

A Usability Assessment of the Effect of Less Literacy on the Use of Instructional Videos and Information Architecture

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A Usability Assessment of the Effect of Less Literacy on the Use of Instructional Videos and
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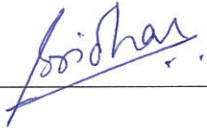
Dedication

Dedicated to my parents, Bimal and Meera Medhi, for all the encouragement and strength from over the many years, and to my baby girl, Tara, for providing the impetus to take this thesis work to completion.

Approval

This thesis “A Usability Assessment of the Effect of Less Literacy on the Use of Instructional Videos and Information Architecture” by Indrani Medhi Thies is approved for the degree of Doctor of Philosophy (Ph.D.).

Examiners





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Declaration

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Abstract

Today Information and Communication Technologies (ICTs) are reaching in the hands of people in the remotest corners of the world, from mobile phones and PCs to handheld tablets. If we consider mobile phones, as of 2014 there were 6.9 billion accounts in the world and 78% of the subscribers lived in developing countries. However just having access to ICTs does not mean being able to use them to one's advantage. There might be various intermediating factors that impact the use of these devices-- low-literacy, language barriers, lack of technology experience, lack of ICT maintenance infrastructure, etc.

In this thesis we start by focusing on one of the factors—textual low-literacy. About 775 million people in the world are completely non-literate, and even more are able to read only with great difficulty and effort. Many such users avoid complex functions, and primarily use phones for synchronous voice communication only. There is a significant body of previous work that looks at UI design for low-literate users, focusing on graphical and voice UIs to help low-literate users overcome the need to read text. While some of this work shows that low-literate users prefer non-textual interfaces, there still remains other cognitive challenges that impede use of UIs even when they are Text-Free and do not require any reading. One of these challenges, as suggested by anecdotes in related literature and *our own* previous work is navigation of hierarchical UIs. The other challenge is transferring learning from instructional videos and applying to actual practice.

In this thesis we study how transfer of learning of video-based skills can be enabled through presentation of instructional videos, and how navigation of ICT UIs can be enabled through appropriate Information Architecture design, even where the UIs are Text-Free. We focus on first-time usage scenarios with minimal training. We conduct controlled usability studies of variations of instructional videos, with first-time, low-literate users from urban slum communities in Bangalore, India. This is in the context of training for use of a vacuum cleaner. We follow this up with controlled usability studies comparing different Information Architecture designs of graphical UIs—a list design, a shallow and a deep hierarchy – presented on a PC and mobile phone, again with first-time, low-literate users from the same communities. Our second and third experiments are conducted in the context of finding 40 familiar household items.

The main contribution of our thesis is concrete proof of hypotheses from three controlled experimental studies that skills required for transfer of learning of video-based training, and for navigation of hierarchical UIs, are correlated with levels of textual literacy, even when the UIs are Text-Free. Based on results from these three experiments, we make recommendations for presentation of training videos for technological appliances and information architecture design for PC and mobile phone UIs for search tasks of familiar items. In addition, we have some surprising findings that complement or disprove our experimental hypotheses and we list selected ones in our thesis, with directions for future work.

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Abbreviations

- 1) 2D: 2 Dimensional
- 2) 3D: 3 Dimensional
- 3) ATM: Automatic Teller Machine
- 4) BOP: Bottom of the Pyramid
- 5) DG: Digital Green
- 6) DVD: Digital Video Disc
- 7) F: Familiar
- 8) GUI: Graphical user Interface
- 9) HCI4D: Human Computer Interaction for Development
- 10) IA: Information Architectures
- 11) ICT: Information and Communication Technologies for Development
- 12) IQ: Intelligence Quotient
- 13) IVR: Interactive Voice Response System
- 14) PC: Personal Computers
- 15) PDA: Personal Digital Assistant
- 16) Q&A: Questions and Answers
- 17) SD card: Secure Digital card
- 18) SDS: Spoken Dialogue System
- 19) SMS: Short Message Service
- 20) SOP: Standard Operating Procedure
- 21) U: Unfamiliar
- 22) UI: User Interfaces
- 23) USD: United States Dollars
- 24) VCD: Video Compact Disc

Chapter 1: Introduction to the ICT usability challenge among Low-Literate Users

Today Information and Communication Technologies (ICTs) are reaching in the hands of people in the remotest corners of the world even before roads and other basic public infrastructure. The prices of devices are rapidly dropping and people across income groups are getting access to a range of technologies, from mobile phones and PCs to handheld tablets. If we consider mobile phones, as of 2014 there were 6.9 billion accounts in the world and 78% of the subscribers lived in developing countries (ITU 2014). In 2011, in India alone, 63.2% households had a phone (mobile phones and/or landline) while only 46.9% houses had access to a toilet (India Census 2011, NPR). Across the world PC penetration may not be as high as mobile phones. But in the past decade there was a surge in public kiosks and telecentres (Heeks & Kanashiro, 2009; Best & Kumar, 2008; Kuriyan et.al. 2006). A telecentre is a public place where people have shared access to PCs and the internet so they can create, learn, and communicate with others while developing digital skills (telecentre.org retrieved July 7, 2014). Unlike the penetration of mobile phones, the nature of these telecentres was more experimental however. Also, given the pervasiveness of mobile phones, including in rural areas, telecentres may be becoming less and less relevant in recent times.

Whether it is mobile phones or PCs, beyond facilitating communication, these ICTs are transforming the way people send money, manage health, check market prices, engage with government, manage emergency response, and many other things. With the ever increasing access to ICTs, initially there was the narrative of the ‘Digital Divide’ (NTIA, 1995; Chinn & Fairlie, 2004), used to describe the gap between those who have ready access to not just the ICTs but also the skills to make use of them and those who do not have the access or skills to use the same technologies within a geographic area, society or community. This narrative has largely been a dichotomy of digital “haves” and “have-nots”. And there has been both a commercial and an academic discourse around this digital divide. The ultimate goal has been to “bridge” the digital divide by bringing access and affordability to those people for whom ICT access remains largely out of reach. A more recent relevant effort in this direction is the ‘Digital India’ initiative launched by the Government of India in 2015, with a vision to transform India into a digitally empowered society and knowledge economy (<http://www.digitalindia.gov.in/>). The goal of this program is to

make government services available to citizens electronically by improving online infrastructure and by increasing Internet connectivity.

Even outside of infrastructure, affordability and physical access, there are a number of challenges in using technologies among the digital “have-nots”: issues with low-literacy, language barriers, lack of technology experience, etc. In this thesis we look at how User Interface (UI) design can help overcome one of these challenges—low-literacy, to enable the use of ICTs. 775 million people in the world are completely non-literate, and even more are able to read only with great difficulty and effort. Of the non-literate population 85% live in 41 countries, most of which are between developing to least developed (UN News Centre, 2012).

The magnitude of the low-literacy challenge facing many countries today is further complicated by the strong links between literacy and poverty (UNESCO, 2006). For example, there is a significant negative correlation between measures of poverty and the adult literacy rate, at both the international level and at the subnational level in countries such as India; that is, where poverty rates are higher, literacy rates tend to be lower. And among poor populations across the world even the literate typically tend to be novice users of ICTs. Many such users avoid complex functions on mobile phones—eg. saving contacts in the phone book, sending and reading SMS, setting alarms, doing Bluetooth transfers, etc.-- and primarily use phones for synchronous voice communication only (Chipchase 2005). Many low-literate people find even the contact function on their phones too difficult to use, so they dial numbers from scratch every time they need to make a voice call. To meet constraints in literacy and the availability of technology there is intermediated use of ICTs, which is a common work-around in low-income areas. Here non-literate or poor members of a community seek help from individuals in the community who either have access to technology (e.g., ownership) or are more digitally-literate (e.g., a friend or relative who can read or knows how to use a device) (Sambasivan et.al. 2010). But this causes dependence on the digitally-literate friend or relative.

Within ICT tools and techniques instructional videos are an increasingly popular mechanism for teaching people how to perform a wide range of skills and tasks. Websites such as howcast.com, e-how.com and youtube.com contain a trove of instructions for cooking, repairing, building, and all manner of other things. In the domain of development, Digital Green (Gandhi et.al. 2007) has

had success using human-mediated video for teaching agricultural techniques to farmers in rural India. There are other examples of videos being used in development for teaching microfinance (Video for Development), agro-marketing (Video for Development), and watershed management (Samaj Pragati Sahyog).

Another mechanism used in ICTs for presentation of information are Information Architectures (IAs) designed in the form of hierarchies. IAs enable navigation of enormous information systems by concentrating on a few issues at a time. One of the principle benefits of hierarchical IAs is that space needed for navigation can be reduced by nesting.

In this thesis we explore how independent learning of ICTs can be enabled through presentation of instructional videos, and how independent navigation of ICT UIs can be enabled through appropriate Information Architecture design. We conduct controlled usability studies of variations of instructional videos with first-time, low-literate users from urban slum communities in Bangalore, India. Low-literacy for our purpose is defined in the context of *textual* low-literacy. We follow this up with controlled usability studies comparing different Information Architecture designs of graphical UIs on a PC and mobile phone, again with first-time, low-literate users from urban slum communities in Bangalore, India. We close with a set of design recommendations for ICT instructional video presentation and UI navigation for first-time, low-literate users, contributions of this thesis and future work.

Chapter 2: Motivation from Previous Work in Designing for Low-Income Communities

The discussion on the ‘Digital Divide’ (NTIA, 1995; Chinn & Fairlie, 2004) first started in the United States of America as an economic and civil rights issue in the mid-nineties. The first of three reports was entitled “Falling through the Net: A Survey of the ‘Have Nots’ in Rural and Urban America” (1995), the second was “Falling through the Net II: New Data on the Digital Divide” (1998), and the final report “Falling through the Net: Defining the Digital Divide” (1999). The NTIA’s final report established the existence of the gap between those with access to new technologies and those without. Surveys on household access to telephones, computers, and the Internet were included. It pointed out the challenges ahead in solving the divide and highlighted the significance of several key policies in promoting access. The subsequent reports found that although more households were getting connected, certain households were gaining access to new technologies far more quickly, while others were falling further behind. Although the term started in the US, at present the digital divide is a universally accepted phenomenon and there is growing interest in addressing this divide from across the world.

There is work from a variety of organizations to “bridge” the digital divide between the ‘haves’ and the ‘have nots’. Companies, academic institutions, non-profits and multilateral organizations are looking at how to overcome challenges and make ICT products and services usable, accessible, affordable, and easy to maintain and distribute among low-income communities.

Particularly for the Indian context, researchers have also discussed how the digital can be used as a bridge to overcome existent social attitudes and structures (De Angeli et.al. 2004). In their paper on a contextual inquiry of ATMs in Mumbai, these researchers discussed how ATMs allowed low-income people to escape from discomforts of the class system. According to the paper despite the caste system being forbidden and the Government of India operating a positive discrimination policy towards the lowest classes, India is characterized by a well-defined social framework that differentiates people according to their social class. Relationships between classes are regulated by strict unwritten rules. Upper and lower class people live parallel lives with minimum overlap. This

cultural trait was found to influence many aspects of financial behaviour. Through their study the researchers observed that some study participants from lower classes preferred using ATMs rather than a human teller. The study concluded that technology could potentially act as a means to transcend class barriers, and have unexpected effects on a given culture.

2.1 Commercial work in designing for low-income communities

In the commercial space, one of the first significant thrust in designing (ICT and non-ICT products and services) for low-income communities was arguably leveraged through C K Prahalad's concept of 'Bottom of the [Economic] Pyramid' (BOP) in his work "The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits" (2004). The book discussed new business models targeted at providing goods and services to the poorest people in the world. It consisted of a number of case studies about businesses that have thrived with such models, such as: Casas Bahia, a retail chain from Brazil specializing in furniture and home appliances, which allowed instalment plan purchases for low-income customers; Patrimonio Hoy, a savings and credit housing scheme that allowed low-income families to plan and obtain access to services and building materials; Bank of Madura, and its rural bank network that allowed ICICI bank to add 1.2 million rural customers in its merger and expansion, making it one of India's largest private sector bank; Aravind Eye Hospital, service provider for ophthalmological services performing almost 3,50,000 eye operations in a year and 60% of it at low or no cost; Jaipur rugs, manufacturer of handmade rugs that enabled poor artisans and weavers to become entrepreneurs; and Project Shakti, at Hindustan Lever (HLL), a consumer goods company that trained rural women's Self Help Group members to operate as a rural "direct-to-home" sales force, educating customers on health and hygiene and benefits of HLL brands. Prahalad's book made a case for the fastest growing new markets and entrepreneurial opportunities among billions of poor people at the BOP. It showed how this segment had vast untapped buying power, and represented an enormous business potential for companies to learn how to serve what the poor needed.

Apart from the examples mentioned in Prahalad's book there have been a host of other non-digital technology innovations inspired to make products and services accessible and usable by low-income communities. There is General Electric's (GE) ultra-low-cost electrocardiogram (ECG) machine primarily meant for rural India. Usually ECG machines cost about INR 3,05,000 (USD

5000) and a scan about INR 1200 (USD 20), but GE's ECG machine was priced at INR 48,700 (USD 800). More importantly it was easy to use-- was portable, battery-operated, and easy-to-repair. There was no monitor and the printer was a kind of ticket printer found on public buses and in movie theatres. The simpler interface made it easier for paramedic staff to use the device with minimal training.

There have been other such low-cost product innovations, in the domain of water filtration, which don't just aim to bring the cost down but are also easier to use. Waterhealth International's innovation for purifying bacterial contamination in collected surface water incorporates the low-cost technology designed for the poor with an effective approach to social marketing and distribution. Each system has the capacity to serve up to 5,000 people a day, though its easy-to-use modular design can be configured to serve communities of up to 10,000 people. Among other low-cost, easy-to-use consumer facing models, is Tata's Swach where water purification is carried out using the low-cost technology of processed rice husk ash impregnated with nano silver particles to destroy disease causing bacteria. The non-electric purifiers are available for as less as INR 1,150 (USD 19). In a similar line of products, there is HLL's Pureit, which removes harmful parasites and pesticides through an activated carbon filter and uses a programmed chlorine release technology to target and remove invisible harmful viruses and bacteria. The manual water fill models are available for as less as INR 1,200 (USD 20).

From the above examples we see that there is currently a growing interest among corporations, to understand and design products and services to address the needs and aspirations of low-income populations worldwide.

2.2 Related work in Human-Computer Interaction for Development

Even from a fundamental research perspective, there has been much interest in designing for low-income communities, especially in the domain of Human-Computer Interaction for Development (HCI4D). Low-income communities are often low-literate (UNESCO, 2006), and as discussed in the Introduction chapter, research shows that many low-literate users avoid complex functions on mobile phones—e.g. saving contacts in the phone book, sending and reading SMS, setting alarms, doing Bluetooth transfers, etc. Instead they primarily use phones for voice calls only (Chipchase 2005). More recently in low-income contexts however, researchers have observed the phenomenon

of intermediation, where users who are low-literate employ a common work-around to meet constraints in literacy and the availability of technology (Sambasivan et.al. 2010). In intermediated use non-literate or poor members of a community often seek help from individuals in the community who either have access to technology (e.g., ownership) or are more digitally-literate (e.g., a friend or relative who can read or knows how to use a device). But this kind of ICT use causes dependence on the digitally-literate friend or relative.

This has sprung up the research question: how can ICT UIs be designed such that low-literate users independently access a broad range of services and utilities that are increasingly available to them?

2.2.1 Design of UIs for Low-Literate Users

Researchers in the domain of HCI have been investigating the above question, exploring how UIs can be made more user-friendly for users who have been termed as low-literate and novice. Most of these users have low levels of formal education and limited exposure to ICTs. One major category of the research in this area is in graphical UIs. While this work is not about ICT UI navigation per se, it is relevant for our purpose, because like us these studies also use graphics in their UIs.

- **Graphical UIs**

A number of early UI studies in HCI4D recognized the value of imagery and advocated extensive use of graphics to help overcome the inability to read text, though there were differences in how they each used graphics (Grisedale et. al. 1997; Huenerfauth, 2002; Parikh et.al. 2003). While all of these papers emphasized the importance of user-centeredness in graphics, the first one used stick-figure style icons in health information data collection among rural health workers (Grisedale et. al. 1997), the second discussed the trade-off of different styles of graphics (Huenerfauth, 2002)—static hand-drawn images, photographs, video, animation, finding that static hand-drawn images with audio annotation was the best understood by low-literate users. Finally the third study used representational identifiers such as icons and images but in a financial management system for rural microfinance (Parikh et.al. 2003).

More recent work has also reinforced the use of graphical icons and pictures for low-literate users across a variety of domains: ‘Igwana’ used icons to navigate large and complex data sets found on

the Web (Bhattacharya and Feldman, 2012); smartphone applications in agriculture used icons and photos (Agrawal et.al. 2013); ‘Parichaya’ used icons for medication adherence among tuberculosis patients (Seth and Sorathia, 2013); ‘WATER alert!’, a water delivery alert and quality reporting system for better citizen involvement also used icons (Brown et.al. 2012). Graphical icons and pictures have also been used in comparison studies of GUI widgets and navigation styles in fluid and nutrition monitoring among chronically-ill patients (Chaudry et.al. 2013).

Within graphics in UIs for low-literate users, there is work that has looked at the use of colour in imagery. Researchers have designed an icon and colour based visual phonebook, ‘Rangoli’, for non-literate people and have showed that colours could help them sort and identify contacts, though within a limited range (Joshi et.al. 2008). Another group of researchers also designed a phonebook with colours and icons and showed that novice users were able to use it in managing their contacts (Wiedenbeck, 1999).

So far we discussed examples of graphical UIs designed for low-income, low-literate users. Though it is not always easy for these users to spend on graphical phones, touch-screen or otherwise, hence a number of recent studies have looked at the use of low-end phones for the design of voice UIs. We discuss a few of these examples below.

- **Voice UIs**

Outside of graphics, a number of recent studies in voice UIs use Interactive Voice Response (IVR) systems, where users can navigate services through a simple mobile phone call with spoken menu output and keypad input navigation. There are a number of examples of IVR systems that use pre-recorded or dynamically generated audio to direct users on how to proceed within the system. Examples of IVRs aimed at low-literate users include: Avaaj Otalo, a Q&A forum for small-scale farmers, to ask and listen to queries on a wide range of agricultural topics (Patel et.al. 2010); CGNet Swara, a citizen journalism portal, where rural users can report and listen to news stories of local interest (Mudliar et.al. 2012); TAMA (Treatment Advice by Mobile Alerts) that provides treatment support to people living with HIV/AIDS in developing countries, who are on antiretroviral therapy (Joshi et.al.2014); Polly, a voice manipulation and forwarding system, to virally spread job information through entertainment (Raza et.al. 2013, Raza et.al. 2012); and Gurgaon Idol, a

community talent competition, in collaboration with a Community Radio station in which community members could call an IVR system to record their songs, and vote to select the best songs (Koradia et.al. 2013).

Within voice UIs for low-literate users, there are also spoken dialog systems (SDS) where users can navigate services through a simple phone call with spoken menu output with speech input navigation. Researchers have looked at Healthline, an information access system to be used by Community Health Workers in Pakistan (Sherwani et.al. 2007). Research has shown that by limiting the vocabulary to less than 100 words, one can develop a working speech-based system for resource-constrained languages using a system called SALAAM (Qiao et. al. 2010). Results showed that a well-designed SDS could significantly outperform an IVR system for both low-literate and literate users.

Both IVRs and SDSs use complex information architectures, which we study in our thesis. However, we do not look at either IVRs or SDSs for our work here. Instead we build on anecdotal evidence about challenges in the use of complex information architectures from our own previous studies in *GUIs* alone. We elaborate on this in section 2.3.

- **The “Text-Free UIs” project for First-time, Low-Literate Users**

In addition to the above there is closely relevant research in audio-visual UIs aimed at low-literate users, to be used through minimal training. This is one of the first works in HCI4D where researchers have formally tried defining literacy and used years of formal education as the proxy. The research began by characterizing non-literacy as the inability to read. Given this inability the researchers designed “Text-Free UIs” with the goal of establishing design principles for computer-human interfaces that would allow a non-literate person, on first contact with a PC or a mobile phone, to realize useful interaction with minimal external assistance (Medhi et.al. 2011; Medhi et.al. 2009). The usage scenario Text-Free UIs were designed for is first-time usage through minimal training. First-time usage is when target participants use an application for the very first instance, in the real-world or within a study set-up. Within a study, participants may have used low-fidelity prototypes of the application informally through the iterative cycle, but most

observations are often based on the formal evaluation of the final prototype. They might receive training—in-person, through video, or other means-- but this is usually on a single instance just before the formal evaluation.

Through design ethnography, iterative prototyping and rigorous usability evaluations, involving more than 700 hours spent in the field and 570 study participants from low-income, low-literate communities across rural and urban areas of India, the Philippines and South Africa, design principles were established that used combinations of voice, video and graphics. The communities studied had the following characteristics: (a) low levels of formal education (< Grade X); (b) no experience whatsoever using a computer; and (c) household income less than INR 9000 (USD 150) per month.

The Text-Free UI principles were applied to designing three PC and mobile phone-based applications:

1) Job-search for the informal labour market (Medhi et.al. 2008): The goal was to use a computer-based system to help match low-income domestic workers from urban slum areas with potential middle-class employers, in Bangalore, India. This was envisioned to be an online job portal for the informal labour market. The domestic helpers would see a “Text-Free” version of the textual job-posting from the employers, at a public kiosk.

2) Health-information dissemination (Medhi et.al. 2007): This was a health-information dissemination system installed as a public kiosk for low-literate patients in hospital waiting rooms. Ratio of care givers to patients served is very low in developing countries like India (1:2000); as such there are long wait-times at public hospitals. (Ministry of Health and Family Welfare, retrieved March 2015). The usage scenario was for during such wait times, when patients could use a “Text-Free UI” to look up preventative health information.

3) Mobile-phone-enabled banking and payments (Medhi et.al. 2009): This was designed as a stored-value account with the mobile phone as the primary transaction device. The usage scenario was that currency cash-in/cash-out would be done at retail outlets intermediating between a bank/telco and customer. Most of the existing services in mobile-banking at the time of this research had text-based services [G-cash (<http://www.GCash.com.ph/>), Eko (<http://eko.co.in/>),

Wizzit (<http://www.wizzit.co.za/>) and M-PESA (<http://www.safaricom.co.ke/index.php?id=228>)]. Low-literate users experienced a lot of challenges using these services (Medhi et.al. 2009). It was envisioned that low-literate users could instead use “Text-Free UIs” to access these services on their phone.

A number of design principles were established in Text-Free UIs research, but we list only the most relevant ones to our thesis here:

- **No text; liberal use of graphics and imagery (Medhi et.al. 2007)**

The researchers in the project knew that for all applications the information had to be in graphical form, since target users were not generally literate. While this was an obvious feature, the exact nature of the graphics can make a huge difference. It was observed that users recognized semiabstract cartoons (as shown in Fig. 1 below) and photographs much better than abstract graphics (like stick figure style icons). These semiabstract cartoons were sketched by the researchers and tested extensively on the field. For more specific information, the representation could be through photographs. We apply this principle in our thesis investigation in identifying optimal information architecture where presentation of information on the UI required specificity.

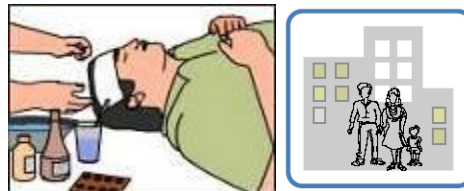


Fig. 1: Semiabstract cartoons of the health information app and job-search app

- **Use of "full-context" video (Medhi & Toyama, 2007)**

It was observed that in spite of users’ understanding of the UI mechanics, they experienced barriers beyond the inability to read in interacting with the computer: lack of awareness of what the PC could deliver, fear and mistrust of the technology, and lack of comprehension about how information relevant to them was embedded in the PC. These challenges were addressed also with full-context video, which included television soap-style dramatizations of how a user might use the application in a given scenario and how relevant information came to be contained in the computer, in addition to a tutorial of the UI. The full-context video would be looped at the beginning of any

given application. It was observed that introduction of a full-context video dramatically improved task completion on any given application for our users. However there still remained challenges which users experienced in interacting with UIs. We use full-context style demonstrations for training our thesis studies' participants both in the instructional video investigations as well as the information architecture investigations.



Fig. 2: Screenshots of full-context video for the job-search app

- **Avoid menus that require scrolling (Medhi et.al. 2011; Medhi et.al. 2009)**

Working with mobile phones it was observed that vertical scrollbars were not initially understood by many of users. They did not realize that there were functions “beneath” what was displayed. Explicit demonstrations were required to teach what scrollbars were and how to use them. This group coincided almost entirely with users whose mobile use was restricted to making voice calls. Instead of scroll bars that depict the continuous page paradigm, the items were divided to be displayed on separate pages with full screen view and explicit arrow symbols were used on individual pages to go to the previous and next screen. We apply this principle in our thesis research in identifying optimal information architectures.

The above mentioned principles were applied along with other principles (not mentioned here) to designing Text-Free UIs and followed with controlled usability studies. Rigorous user evaluations with test participants confirmed that the designs were strongly preferred over standard text-based interfaces and that Text-Free UIs were of value to low-literate users (Medhi et.al. 2011; Medhi et.al. 2007). However, there still remained a lot more to be accomplished in order to make ICT UIs truly usable by low-literate audiences. Our thesis research aims at filling some of the gaps in this Text-Free UIs work.

2.2.2 Training on existing UI use

Following the research in Text-Free UIs, we did our own voluntary work with Digital Green (DG) (<http://www.digitalgreen.org> Retrieved on May 25, 2014), a non-governmental organization that works in agriculture training. Unlike in Text-Free UIs, where the goal was to *design* UIs for first-time, low-literate users, our work in the DG context involved training people with low levels of formal education on the use of UIs for *existing* ICTs. Before describing the details, we discuss the DG context below.

DG has been successful in using mediated instructional video to teach agricultural techniques to smallholding farmers in rural India, Ethiopia and Ghana (Gandhi et.al. 2009). The videos are of local progressive farmers demonstrating best practices in farming and animal husbandry relevant for the local context and in the local dialect of that region. The videos are commonly stored on an SD card and projected against a wall by means of a handheld pico-projector. They are screened to groups of 15-20 rural farmers by a local mediator who engages and moderates the group in discussions.

DG works with local rural mediators who not just screen the videos, but also produce them by shooting and editing them. In our work in the DG project context, we trained 23 mediators (with formal education between grade II and X) to use devices such as pico-projectors, video cameras, Windows Movie Maker software on PCs, based on DG's Standard Operating Procedure manual (Digital Green <http://www.digitalgreen.org/sop>). The mediators we worked with had the following characteristics: (a) low levels of formal education (< Grade X); (b) no experience whatsoever using a computer; and (c) household income less than INR 6000 (USD 100) per month. This work was conducted exclusively in the rural Indian context.

We conducted active in-person demonstrations, instructional videos, and group and individual do-it-yourself exercises during the training sessions. The details of the training module is included in Appendix I. Unlike in the Text-Free UIs research, where the goal was to design UIs for first-time usage, in the DG project context usage of ICT tools was through active training over a three week period. Secondly, the DG context required reading limited isolated words and short phrases in English on the UIs of the pico-projectors, video cameras, and Windows Movie Maker interfaces;

though Text-Free UI was free of any written text. Also unlike in Text-Free UIs, during the DG training we made only informal observations about usage and did not log or record details of individual usage by our mediators. We discuss the challenges gleaned from this experience in the next section 2.3.

2.3 Observations from Text-Free UI studies and ICT training in DG:

While there were differences in the set-up we had anecdotal observations in the DG context, consistent with the Text-Free UI studies, which provided motivation for our thesis research. Before going into the observations that we followed through in the thesis we summarize a few others here. It was observed that people had issues with: a) self-efficacy, the belief that one is capable of performing in a certain manner to attain certain goals (Bandura, 1977); b) vigilance: the ability to maintain attention and alertness over prolonged periods of time (Warm et. al. 2008); c) the ability to prioritize or arrange and deal with instructional information in order of importance; d) the ability for inferring additional constraints to achieve goals or deduce additional details (outside of given instructions) to solve the problem; e) the ability for inferring the unified whole of a learning problem based on specific instructions and examples provided for certain specific tasks; and f) the ability for conceptual organization or mental models—an intuitive perception about how something works in the real world. But these anecdotes did not come up consistently and hence we did not follow them through. Besides these there were more consistent observations, which we describe below.

- **Difficulty in understanding hierarchical organization:**

Overall it was observed that whether in first-time usage or usage through training, minimal reading or no reading, hierarchical IAs that traditional computing software depend upon – menus, folders, and so on – posed challenges for users with low levels of education. The observations though anecdotal were consistent in both the Text-Free UI and DG project contexts.

The first such observation was during usability tests of Text-Free UIs. People had difficulty navigating the branched, hierarchical organization of the job-search UI application. They did not seem to understand the concept of nesting and how a root node (e.g. page of list of jobs) branched to other nodes (individual pages with specific job descriptions from the list). However on the health

information dissemination UI when pages were organized in a flat, linear structure, users seemed more comfortable navigating through them. In this UI, users had to click through a list of pages, each page depicting a symptom (related to diabetic retinopathy) and indicate whether or not they experienced those symptoms by clicking on a tick or cross icon respectively. They understood the navigation in this case by the analogy to the pages of a book (strangely enough, for a group not used to reading). All of these observations were for first-time usage only. There were no observations, in the Text-Free UI project, for how users would use the UIs if exposed for a sustained, longer period of time.

Even though hierarchical navigation on a Text-Free UI is not dependent on reading, it was suspected that other cognitive skills may be required to discriminate specific attributes of the lower-level categories in a hierarchical organization, to combine to form generalized representations of the top-level categories.

During equipment and software training sessions in the DG project context, we had observations similar to the Text-Free UI studies ourselves. We observed repeatedly that even among those mediators who could read limited isolated words and short phrases in English (and were taught to open Windows Live Movie Maker only from the “start menu” option launching the application directly), had difficulties understanding the concept of nesting in tab buttons. The video editing training handout is included in Appendix II. We saw repeatedly that the mediators did not understand how under the tab buttons (“Home”, “Edit”, etc.), different groups and items (“Add videos and photos”, “Add Music”, “Split”, “Trim”, etc.) were organized in the drop-down boxes. Again while adding pictures and videos from “My computer” they did not understand how folders were organized and nested under other folders. *We note that this could have been due to many reasons: memory, attention, reasoning, comprehension, non-intuitive categorization, etc. But since this was an observational study we were unable to identify the cause(s) conclusively.* Our mediators had to be explained repeatedly about what items came under which tabs. We also drew flowcharts on paper that explained the various paths and selections that had to be made to go about a given function. Our mediators carried these flowcharts with them as reference sheets and tried rote learning them. There were 8 people (out of 23) who received training for use of Windows Movie Maker. At the end of about 3 weeks only 2 out these 8 people were able to use Movie Maker for

editing short 10 minute movies with basic transitions and effects. Both of these people had education up to Grade X.

Similarly on the pico-projector interface, which was relatively more simplified, mediators again did not understand the concept of nesting: how under the tabs (“videos”, “settings”, etc.), different items such as “list of videos”, “language”, “screen aspect ratio”, etc.), were organized. Similar to the Movie Maker experience we drew flowcharts on paper that explained the paths and selections that had to be made to go about a given function, which our mediators rote learned.

The challenges faced by users in the DG project context in using hierarchical nesting were confounded by having to read isolated English words and short phrases. This is a potential limitation of this part of our study since in our main thesis studies (like in the Text-Free UI research) people were not required to read any text. Additionally, our thesis research, like the Text-Free UI research, focused on design of UIs for first-time usage with minimal training before usage. In the DG context usage of ICT tools was through active training over a 3 week period.

In summary, whether for first-time usage or usage through active training of 3 weeks, in the Text-Free UI research and our own work in the DG context, we observed that low-literate users experienced problems while using hierarchical categorization. Later in our controlled studies we will see how low-literate participants fared on the different Information Architecture designs of graphical UIs presented on PCs and mobile phones. But for now we describe below another consistent observation from the Text-Free UI studies and DG training context that we followed through.

- **Difficulty in transferring learning in video-based skills training:**

During equipment use training sessions in the DG project context, we observed that our low-literate mediators had difficulty in learning instructions from instructional videos, and then applying it to actual usage. The videos had minimum effect in terms of motivating the mediators. Sometimes our mediators did not understand that what they had observed in the video had to be applied to the ICT tools we were training them on. Other times they could not grasp details and had a hard time recalling the videos while using the tools. There were still other times when some of the mediators

found it difficult to remain attentive and vigilant while the videos were playing. *These problems could be due to difficulty in comprehension, memory, attention, etc. but because ours was an observational study we could not establish the causes conclusively.* There was of course variation in the individual learning abilities of the users, but overall it seemed like the mediators had difficulties comprehending the instructions, and then transferring that learning to using the equipment. We also observed that performances on the actual tool was usually worse when there was some difference in the feature of the tool from what was featured in the video.

The above is reinforced by similar observations during full-context video studies (Medhi & Toyama, 2007) of the Text-Free UI project. At the beginning of any given application, there was a full-context video which had a tutorial of how to use the UI. This tutorial was wrapped into a television soap-style drama on how a user might use the application in a given scenario. It was observed that even while the narrative of the full-context video seemed to instil a lot of confidence, low-literate users still experienced some difficulties comprehending the instructions in the video, and translating that information to actual practice. The full-context video provided a shift in concern, from anxiety about how to use the device to concerns about the content itself. Still, just transferring what they saw in the video to actual usage seemed challenging for low-literate users. Even though video-based instruction is not dependent on reading, we suspected other cognitive skills may be required to comprehend the instructions demonstrated in the video, and to then transfer that learning to actual implementation in other real-world tasks that are: a) the same or, b) similar. For instance, identify common attributes between video demonstrations and real-world tasks, and apply them on the actual tool to the same tasks or adapt to attributes that are different.

In summary, whether for first-time usage, or usage through 3 weeks active training, in the Text-Free UI research and our own DG work, we observed that low-literate users experienced problems transferring learning from instructional video-based skills training.

In the two above sections we discussed difficulties among low-literate users in: a) transferring learning in video-based skills training and, b) understanding hierarchical organization, in the Text-Free UI and DG project contexts. In this thesis we study the presentation of ICT instructional videos and design of information architecture in graphical UIs for first-time, low-literate users with respect to cognitive skills required in the above two conditions.

Like in the Text-Free UIs study context our thesis studies were designed for first-time usage through minimal training. First-time usage in this context is when target participants use an application for the very first instance in a study set-up. They might receive training—in-person, through video, or other means-- but this is usually just before the formal evaluation. We chose to focus on first-time usage scenarios, out of academic curiosity, while understanding that communities have their own mechanism, strategy and pace of adopting and appropriating ICTs. Examples of real world first-time usage scenarios for our target population include: using public kiosks at places like railway and bus stations; using any personal device for the very first time where the first experience is crucial for instilling trust in a system, such as ATMs, mobile money transfer services. There could be informal training involved in all these scenarios—e.g. watching over the shoulder of another person using the system-- but it is just before the actual usage.

Researchers in HCI for Development have taken different approaches to assistance and training for technology use by novice and low-literate users. Consistent with our dissertation, a number of UI studies targeted at low-literate users have focused on first-time usage with training *only just before* the usability tests, but each of them for a different domain (Cuendet et.al. 2013, Medhi et.al. 2011, Parikh et.al. 2003, Griesdale et.al. 1997). The first application was for agriculture video-search among low-literate farmers (Cuendet et.al. 2013); the second for job search among low-literate domestic workers, health information dissemination among low-literate patients, and mobile money transfers among low-literate users (Medhi et.al. 2011); the third a microfinance system for low-literate users (Parikh et.al. 2003); and the fourth a health data collection system for low-literate health workers (Griesdale et.al. 1997). Research has shown that the outcome of usability studies can be strongly impacted by providing focused training to users *just before* usability tests, like in our approach. In a study exploring data collection with novice health workers in India, it was seen that in first-time usage through training, done *just before* the formal evaluation, there was only one error during the whole study testing a live operator interface (Patnaik et.al. 2009).

What we discussed in this section are anecdotal observations from the Text-Free UIs and DG context in difficulties among low-literate users in: a) transferring learning in video-based skills training and, b) understanding hierarchical organization. Since we decided to look at first-time usage as a *theoretical* investigation, going forward in the next Chapter 3, we study the theoretical

underpinnings of transfer of learning and hierarchical UI navigation. We understand that in order to study these two domains we need to look at research in the domain of cognitive science related to literacy as well, which we do as a follow up. In chapter 4, we present our research hypotheses that we distilled from the Text-Free UI studies and the DG project observations. We then present the experimental designs with methodologies and results from the controlled studies. Chapter 5 discusses what our research results mean for design implications for UIs for first-time, low-literate users. Finally, chapter 6 concludes with the research contributions made through this dissertation, and a few directions for future work.

Chapter 3: Theoretical Underpinnings

In the previous chapter we discussed anecdotal observations from Text-Free UI studies and the DG project context, which showed that low-literate users face difficulties in transferring learning in video-based skills training and understanding hierarchical organization. In this chapter we study the theoretical underpinnings of three relevant areas of research, a) transfer of learning, b) hierarchical UI navigation and, c) cognitive science research related to literacy. We study these through the lens of design because of the domain of the thesis and our background in design.

3.1 Cognitive science research related to literacy

We understand that in order to study the domains of transfer of learning and hierarchical UI navigation and their relation to literacy, we need to look at research in cognitive science more generally related to literacy. And we do a review of related work here.

There have been studies in the cognitive sciences that support the hypothesis that formal education is correlated with general cognitive skill development. In the studies mentioned subsequently, years of formal schooling or reading-writing ability at the time of tests have been used as proxies for the overall education levels of study participants.

A study on the influence of formal schooling on intelligence and its cognitive components suggests that much of the causal pathway between IQ and schooling points in the direction of the importance of the quantity of schooling one attains (highest grade successfully completed) (Ceci, 1991). Schooling fosters the development of cognitive processes that underpin performance on most IQ tests. The study implies that this influence can be interpreted in two ways: 1) Students acquire general knowledge and processing strategies important for task performance, and 2) formal schooling provides students with attitudes, values, and motivation that are important in testing situations.

In addition to the skills of reading and writing, educated people seem to acquire cognitive skills and strategies for efficient processing of information (Van Linden & Cremers, 2008). This study investigated the proficiency levels of functionally non-literate persons on a number of cognitive skills [language processing skills (reading, writing, listening, fluency, ability to understand

instructions, and learning capabilities). The remaining of the tests in this study did not require the skills of reading and writing. They included testing for visual organization and visual memory skills along with speed of cognitive processing (Rey Complex Figure Task (RCFT) (Rey, 1941). The respondent was required to copy a complex abstract figure, after which they were asked to draw the figure from memory both 3 and 30 minutes after having completed the copy. This study also measured people on mental spatial orientation based on the Spatial Ability Task (SPAT) (Neerinx, Pemberton & Lindenberg, 1999). Participants were presented with a sequence of 40 tasks on a computer screen which required mental rotation of 3D geometric objects. There was also an Attention test measuring attention, mental alertness and divided attention. The respondents' task was to steer a moving figure with a joystick towards a central point on the screen. And finally, a version of the Generalized Self-Efficacy Scale was administered (Schwarzer & Jerusalem, 1995). This was designed to assess optimistic self-beliefs of people required to cope with a variety of difficult demands in life. It was found that the functionally illiterate people performed worse on all the tests which measured cognitive abilities, including the tests that did not require reading and writing. In our experimental studies we also test people on skills of transfer of learning and navigation of UI hierarchies, which do not require any reading or writing.

Likewise, several other behavioural studies have demonstrated through empirical research that education level correlates with various cognitive skills, by comparing literate and lesser literate/non-literate test participants—

a) language tasks (such as repeating pseudowords, memorizing pairs of phonologically related words compared to pairs of semantically related words, and generating words according to a formal criterion, etc.) (Abadzi, 2003; Castro-Caldas, 2004; Morais et.al. 1979; Reis & Castro-Caldas, 1997; Manly, et.al. 2003). Phonological awareness is the understanding that spoken language is made up of distinct sounds. Teaching how to segment words into phonemes improved reading scores of older Portuguese semi-literate farmers. And it was found that semi-literate people were much better at this skill than non-literate subjects (Abadzi, 2003). Researchers found evidence from an anatomical study that the absence of school attendance at the usual age constitutes a barrier for the development of certain processes that serve behavioural functioning (Castro-Caldas, 2004). Differences between groups of literate and non-literate subjects were found while dealing with phonology. Other researchers found that non-literate adults could neither delete nor add a phoneme

at the beginning of a non-word; but these tasks were rather easily performed by people with similar environment and childhood experiences, who learned to read rudimentarily as adults (Morais et.al. 1979). Another group of researchers have found that non-literate people used strategies that are good for semantic processing, but inadequate for phonological analysis, while literate individuals were able to use several parallel running strategies (Reis & Castro-Caldas, 1997). Using reading tests researchers have also found that literacy skills were protective against memory decline among a group of ethnically diverse elders in New York city (Manly et.al. 2003). In our experiments we do not test our study participants in any language tasks. Nevertheless it is useful to look at related studies as language tasks require cognitive skills much like transfer of learning or navigation of UI hierarchies do.

b) general self-efficacy (the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations) (Bandura, 2005; 1977). Self-efficacy beliefs determine how people feel, think, motivate themselves and behave (Bandura, 2005). In one study of cognitive abilities of functionally non-literate users, people reported that they would feel anxious when using an ATM or ICTs in general (Van Linden & Cremers, 2008). In our experiments we do not test our study participants on general self-efficacy tasks per se. Nevertheless it is useful to look at related studies since in our experimental studies we do assess how participants think and feel about themselves during testing.

c) visuospatial and visual organization (such as figure copy of a cube, house, Rey-Osterrieth complex figure etc., and construction of figures with varying degrees of complexity related to rotation, distortion and disarticulation) (Ardila, et.al. 1989; Matute, et.al. 2000; Reis et.al. 2001). Researchers found that all the visuospatial tasks showed large, highly significant differences between the educational groups considered—non-literate and literate professionals. Differences were found to be statistically significant in the non-literate group, and men always performed better than women but only in the non-literate group (Ardila et.al. 1989). Other researchers explored the performance of non-literate individuals as compared to that of semi-literates and literates in order to see the effect of reading and writing abilities on constructional tasks (Matute et al. 2000). Each participant was asked to construct 4 figures based upon models having varying degrees of complexity. It was found that non-literates generally made more errors than semi-literates and semi-literates more than literates. Other studies in visual and visuospatial skills have shown that

participants with limited formal education performed significantly worse on immediate naming of two-dimensional representations of common, everyday objects compared to well-educated participants, both in terms of accuracy and reaction times (Reis, et.al. 2001). Abstract icons have been known to be less recognized by participants with limited education— they possibly have difficulty integrating details of 2D line drawings into meaningful wholes (Castro-Caldas, 2004). In our experiments we test people on navigation of graphical UIs that are a visuospatial means for expressing and communicating ideas.

3.1.1 Cognitive science research related to literacy in the developing world

Most of the above work is undertaken in developed regions—North America and Western Europe—and therefore, is subject to caveats of cultural bias that may differ in other geographies. Nevertheless, the strength of the evidence suggests that formal education can shape cognitive skills beyond the mere ability to read and write. If anything, in environments where standards of education are even poorer, we might expect differences in cognitive skill arising from educational quality to be even more pronounced.

In studying the impact of the Soviet social revolution on rural Islamist populations of Uzbek and Kirghiz origin as early as in the 1930s (Luria, 1974), it was demonstrated that people with a primarily graphical reflection of reality showed a different system of mental process from people with a predominantly abstract, verbal, and logical approach to reality, in tasks involving sorting, imagination and self-analysis. Participants had to undertake tasks that required abstraction and generalization, specifically the comparison, discrimination, and grouping (or classification) of objects by picking their features according to abstract semantic categories.

There has been limited work among developing world communities in Nigeria and the Philippines, to understand the impact of literacy on cognitive processes (Akinaso, 1981; Bernardo, 2000). In his essay ‘Literacy and Individual Consciousness’, the author used first-hand experiences growing up in his native small village in Nigeria to discuss how literacy impacts not just reading and writing, but also cultural traditions, linguistic behavior, socio-economic organization, cognitive processes, and child development (Akinaso, 1981). The author considers individual consciousness a significant part of literacy. According to him individual consciousness is, “used as a shorthand for

the totality of an individual's knowledge, thoughts, beliefs, impressions, and feelings and the ways these are represented in behaviour, especially reading and writing". He discusses two main views of literacy: causal and facilitating. Literacy as a causal agent means that literacy itself creates new cognitive skills. Literacy as a facilitating agent means that literacy makes it easier to acquire these cognitive skills.

The other work studies five rural and urban low-income communities in the Philippines and compares their performance on a number of cognitive tasks involving conceptual organization, conceptual categorization, conceptual comparison, deductive reasoning and explanation (Bernardo, 2000). This is done through quasi-experimental approaches and by drawing upon an ethnographic study. The participants are categorized as non-literates, non-formal literates and formal literates. Results showed that there was no evidence of direct effects of literacy on thinking and the differences between formal and non-formal literates were such that they pointed to schooling rather than literacy effects. However one of the limitations is that there is little explanation about the ways in which non-formal literates acquired their literacy. There is however discussion provided on how different cognitive approaches to thinking skills are evident in communities with relatively high degrees of literacy integration, when applied to community activities and practices.

Both the above studies are relevant for our purpose. They both show that literacy, whether formal or non-formal, enables some cognitive skills beyond reading and writing. However, none of these studies are done from the perspective of interaction with ICTs and do not call out implications for UI design. Our thesis research aims to fill in this gap by studying the cognitive skills of transfer of learning and hierarchical UI navigation among low-literate users in the developing world, more specifically in India, having little or no education. We conclude by identifying implications for UI design for low-literate users. In the following sections we look at related literature, first in transfer of learning, followed by that in hierarchical UI navigation.

3.2 Transfer of learning:

There is a significant body of work in transfer of learning mostly in the education literature. Most of these though have been conducted among adult literate users or school-going children. Nevertheless we describe some examples here to demonstrate the ways in which transfer happens. Many of these examples speak to the need for training in one context to transfer to another.

The classic investigation of transfer of learning was conducted by the renowned educational psychologist E. L. Thorndike in the first decades of the 20th century. Thorndike examined the proposition that studies of Latin disciplined the mind, preparing people for better performance in other subject matters. Comparing the performance in other academic subjects of students who had taken Latin with those who had not, it was found that transfer depended on "identical elements" in two performances (Thorndike, 1923; Thorndike and Woodsworth, 1901). This included the influence of training in the estimation of magnitudes on the ability to estimate magnitudes of the same general sort, i. e., lengths or areas or weights, differing in amount, in accessory qualities (such as shape, color, form) or in both; the influence of training in observing words containing certain combinations of letters (e.g., s and e) or some other characteristic on the general ability to observe words; etc.

More recent research says transfer of learning occurs when learning in one context or with one set of materials impacts performance in another context or with other related materials (Perkins, 1992). For example, learning to drive a car helps a person later to learn more quickly to drive a truck, learning mathematics prepares students to study physics, etc. Usually the context of learning (classrooms, exercise books, tests, simple streamlined tasks) differs markedly from the ultimate contexts of application (in the home, on the job, within complex tasks). Even if the later situation is very similar, there will be some contrasts - perhaps time of day or the physical setting (Perkins and Salomon, 1992). In fact, the taxonomy of transfer suggests six degrees of similarity between the context of learning and application: non-specific transfer, application transfer, context transfer, near transfer, far transfer and displacement or creative transfer (Haskell, 2001; Roussel, 2014).

- Non-specific transfer: Because all learning depends on some connection to past learning, all learning in this sense is transfer of learning.
- Application transfer: Applying what one has learned to a specific situation e.g. after having learned about computer programming, transferring knowledge to actually program a computer.
- Context transfer: Applying what one has learned to a slightly different situation in terms of work environment, realization conditions, etc. E.g. producing a table of data identical to the

one learned in training using the same office software, but in a context with less time and frequent interruptions.

- Near transfer: Where the difference between training situation and transfer context is large enough that a certain degree of adaptation is necessary. e.g. transferring experiences associated with driving a car with a manual transmission to driving a truck with a manual transmission.
- Far transfer: Not just differences but major changes in both the transfer context and the learning content to be transferred; high degree of adaption required. e.g. learning about logarithms in algebra and applying this knowledge in assessing the growth of bacteria in microbiology.
- Displacement/Creative transfer: Not only major changes between the training situation and the transfer context, but also the discovery of a new field of application for the learning to be transferred, relative to the content element. E.g. the transfer of registered scientific knowledge in the context of developing new medications.

Researchers have looked for transfer effects between puzzles or games that are isomorphs of one another, sharing the same logical structure but presented or described in very different physical terms. For example, research has focused on the well-known Tower of Hanoi puzzle that required moving three (or more) rings of different sizes among three pegs according to certain rules (Simon and Hayes 1977). One isomorph involved a story about three extra-terrestrial monsters, each holding a crystal globe of a different size. The rules for the monsters passing the globes to one another were logically equivalent to the rules for moving the disks from peg to peg. It was observed that when the relationships between the isomorphs was pointed out, subjects could transfer strategies fruitfully.

Positive findings of transfer, near and far, suggest that transfer can occur in many different ways. Transfer sometimes depends on whether learners have abstracted critical attributes of a situation. In one demonstration researchers presented subjects with a problem story that allowed a particular solution (Gick and Holyoak, 1980; 1983). From subjects that solved the problem, they elicited what the subjects took to be the underlying principle. Then they presented the subjects with another analogous problem that invited a similar approach. Those subjects with the fullest and soundest

summary of the principle for the first puzzle were most successful with the second. These and other results suggest that explicit abstractions of principles from a situation foster transfer. According to experiential learning theory, learning takes place in a spiral process that begins with concrete activity and continues with reflexive observation leading to abstract conceptual generalizations (Kolb, 1984).

In one training experiment, subjects were tested on a transfer task for operating a simple control panel device, used to provide predictions for the time to learn and execute a simple text editor. (Keiras and Bovair, 1986). Different forms of mental model training were compared to a high-quality rote procedure training condition, in which subjects were given the procedure directly. It was found that in the mental model condition subjects constructed a procedure for operating the device, by making inferences from the mental model training materials, which could be difficult to do depending on the amount, complexity, and abstractness of the material. On the other hand, subjects given the procedure directly were far better off. Hence, acquiring procedures from text was found to be superior to inferring them from a mental model.

The above procedure would be challenging though for people who are unable to read text. Worse still, very little has been done from the perspective of adults with low-literacy skills in the transfer of learning literature and we look at a few examples here. In a study with low-literate adults, researchers examined how the transfer of learning occurred in an employment preparation program (Taylor et.al. 2009). Programs involving trainees, instructors and workplace supervisors participated in the investigation. Results indicated that the areas of computer literacy, oral communication and continuous learning were the guide posts for transfer of learning. For example, in the area of computer literacy participants mentioned using the computer—at home or work-- to find additional information received in the classroom. The fundamental skills of reading texts and use of documents transferred to looking up information on search sites.

Researchers have proposed that literacy skill levels (described below) may influence trainees' abilities to take what they learned in the classroom, abstracting critical attributes and transferring that to their job (Bates and Holton, 2004). In this study two distinct groups were identified, the first group of participants had a mastery level of math and reading skills either consistent with their job

requirements or exceeding them. The second group possessed a level of math and reading skills that was below in terms of the requirements of their jobs. Results showed that trainees with lower literacy skills tended to perceive their workplace as an environment that is less supportive to transfer 16 'Learning Transfer System Inventory' skills (LTSI) than those trainees with high literacy skills. The LTSI (Holton et.al, 2000) measures sixteen factors in the learning transfer system that may be barriers or facilitators to transfer learning. Two of the sixteen factors are: i) performance self-efficacy-- the extent to which an individual feels confident and self-assured about applying new abilities in their jobs, and can overcome obstacles that hinder the use of new knowledge and skills on the job. (This reinforces observations about self-efficacy in the Text-Free UI studies and our own DG training contexts); and ii) transfer effort- performance expectations-- the extent to which an individual believes that applying skills and knowledge learned in training will improve his or her performance. This includes whether an individual believes that investing effort to utilize new skills on the job has made a performance difference in the past or will affect future productivity and effectiveness.

The two above studies with low-literate users demonstrate that transfer of learning does happen in low-literate users, though there could be differences in transfer between low-literate and relatively higher-literate users. Both of these studies, however, have been conducted in developed countries—US and Canada—with people who had some ability to read passages, (from memos, bulletins, notices, letters, policy manuals, etc. relevant to their workplace), and maths skills that involved using calculators and formula sheets.

3.2.1 Transfer of learning among low-literate users in the developing world

In two studies, people with low-literacy have been shown to learn poorly from neutral, stand-alone objects (such as a book or an automated system) that contain a set of instructions to be applied across situations (Ong, 2002; Sherwani et.al. 2009). The first is a classical study (Ong, 2002), that examined the impact of the shift from orality to literacy, on culture. It presented an extensive contrast between what was referred to as oral cultures and what as literate cultures. It described writing as a technology like other technologies (fire, the steam engine, etc.) that, when introduced to a "primary oral culture" (which has never known writing) to have extremely wide-ranging impacts in all areas of life of that culture. These include culture, economics, politics, art, and more.

E.g. many of the effects of the introduction of the technology of writing are related to the fact that oral cultures require strategies of preserving information in the absence of writing. These include a reliance on proverbs or condensed wisdom for making decisions, epic poetry, and stylized culture heroes. Writing makes these features no longer necessary, and introduces new strategies of remembering cultural material, which itself now changes.

The second study (Sherwani et.al. 2009) heavily drew on the theory of Orality (Ong, 2002) to discuss various examples of HCI projects from the developing world, particularly India and Pakistan, about how low-literate users use ICTs. It observed that the orality theory provided a unique lens with which to understand oral users. It synthesized and recommended a framework that provided guidelines and testable predictions for design and evaluation of HCI interventions with developing world contexts. Both these studies (Ong, 2002; Sherwani et.al. 2009) suggested that low-literate users and cultures tend to learn better in situ, embedded in concrete situations and practical experience. Both studies however only provided anecdotal evidence for these observations.

The above leaves a gap for research studies that can provide experimental evidence to show how transfer of learning from a neutral stand-alone system, such as instructional video, happens differently between low-literate and literate users. As discussed in the Introduction chapter, instructional videos are becoming an increasingly popular mechanism to teach people a wide range of skills and tasks. *And we already have anecdotal evidence from Chapter 2 that low-literate users experienced problems transferring learning from instructional video-based skills training in the Text-Free UI and Digital Green contexts.* Our thesis research aims to fill in this gap by systematically studying transfer of learning for low-literate users in the developing world, more specifically in India, having little or no education. We do this through controlled experimental studies in Chapter 4, and identify implications for the presentation of instructional videos for low-literate users in Chapter 5. The research question that we investigate is:

Is transfer of learning in video-based skills training difficult for low-literate users? If yes, in what way?

3.3 Hierarchical UI navigation

In addition to transfer of learning, in Chapter 2 we had anecdotal evidence for hierarchical UI navigation being an issue for low-literate users, from previous work in Text-Free UIs and DG. We discuss related literature here.

In an analysis of hierarchical classification skills related to science education (Lowell, 1977), it was said that top-down hierarchies consist of broad inclusive concepts at the top levels, i.e. super ordinate categories, which subsume less inclusive concepts at the lower levels i.e. subordinate categories. And that abstract reasoning skills are necessary to discriminate specific attributes of the subordinate categories, which can be combined to form generalized representations of the super ordinate categories (Project Learnet, retrieved Mar 17, 2010). Traditional computing software is structured in IAs designed in the form of hierarchies, to enable navigation of enormous information systems by concentrating on a few issues at a time. If this study (Lowell, 1977) was right about abstract reasoning being important to understanding hierarchical classification, then abstract reasoning was likely to be one of the critical skills for manipulation of IAs as well.

There is work predominantly from the 1980s that look at the experiences of using hierarchical UIs among literate users, which is relevant for our purpose. The first study examining menu structures was by Miller (1981). He performed experiments with the following structures: a) a menu with a two choice/six-level structure, b) a menu with all 64 choices and, c) an eight choice/two level structure. He found that subjects were slower and less accurate with menus that had two choices at each of six levels and one menu with all 64 choices. Meanwhile, the eight-choice/two-level tree structure proved to be the best when considering both errors and speed. Based on this Miller concluded that the number of hierarchical levels should be minimized, while avoiding crowding at any given level on the display.

Other studies have reinforced Miller's findings. In all of the works discussed below, the breadth of a menu structure refers to the number of menu options present on a given menu, and the depth refers to the number of levels a user encounters as he/she moves through the menu to a target item. In UI tasks requiring speed and accuracy, optimization of the depth/breadth trade-off has been shown to be an important design consideration. This is because depth and number of options significantly affect the response time (Allen, 1983). There have been numerous studies

investigating whether it is better to have a deeply designed menu structure or a broadly designed one and we discuss some of these here.

One study suggested minimizing the depth of menu structures by providing broad menus of eight or nine options (Kiger, 1984). A number of studies have concluded that a broader menu was more effective than a deeper one, though there are individual differences between each of these studies that we describe below (Seppala & Salvendy, 1985; Snowberry et.al. 1983; Wallace et.al. 1987). Most of these early studies compared various types of menu hierarchies, from broad hierarchies with many options per screen and fewer levels, to deeper hierarchies with fewer options per screen and more levels. According to the first study mentioned above (Seppala and Salvendy, 1985), the definition of task difficulty in navigation structures was derived from the distance between the items that need to be found in the hierarchical tree. The farther the items were from each other, the more difficult the task was. The second study mentioned above (Snowberry et.al. 1983) ran memory span and visual scanning tests and found that instead of memory span, visual scanning was predictive of performance, especially in the deepest hierarchies (six levels). The third study mentioned above (Wallace et.al. 1987) compared a broad menu and a deep menu structure under conditions of time stress for novices. And found that time stress both slowed the completion time and increased errors regardless of menu structure.

Researchers have observed that greater depth decreases the speed and accuracy of performance because it involves additional visual search, decision making, and greater uncertainty about the location of target items, though there are individual differences between each of these studies that we describe below (Chae & Kim, 2004; Jacko & Salvendy, 1996). According to the first study (Chae & Kim, 2004), the depth of information structures should be adapted to anticipate screen size, because screen size affects the navigation behaviour and perceptions of mobile phone users. The second study (Jacko and Salvendy, 1996) tested six structures for reaction time, error rates, and subjective preference. They demonstrated that as depth of a computerized, hierarchical menu increased, perceived complexity of the menu increased significantly. The third study (Schultz and Curran, 1986) observed that menu breadth is preferable to depth as well. They described advantages of a broad menu structure as follows: (a) it prevents “path errors” and (b) it minimizes the need to remember the location of items.

Even though studies have shown that menu breadth is preferable to depth, it has been found that excessive breadth can result in a crowded display. Hence, moderate levels of depth and breadth should be implemented (Larson & Czerwinski, 1998). This study investigated if large breadth and decreased depth is preferable, both subjectively and via performance data, while attempting to design for optimal scent throughout different structures of a website.

The optimal menu structure in computers was examined using a simulation model (MacGregor et.al. 1986). The study investigated the issue of the optimal number of alternatives that should be placed on database menu pages. A search-time model made predictions about how the number of alternatives affects the search process and the pattern of errors that will result. Results indicated that with naive users the optimal number of alternatives/page is 4 to 5. These values resulted in the shortest search times, the highest success rates, and the highest preference rankings.

To summarize, most studies agree that hierarchical levels should be minimized, and that having a broader menu is better than having a deeper one e.g. eight choice/two level structure is better than a two choice/six level structure. Such results have been established through various tests of memory span, visual scanning, time related stress, etc. Studies have observed that greater depth decreases the speed and accuracy of performance because it involves additional visual search, decision making, and greater uncertainty about the location of target items. Even though most previous studies have shown menu breadth to be preferable, studies have also called for moderate levels of breadth so as to avoid crowded displays. One study indicates that the optimal number of alternatives per page is 4 to 5, which leads to shortest search times and highest success rates.

Particularly relevant for our research, one study based on PDAs compared linear, hierarchical and cross-linked navigation performance in the context of a search task (Chaudry, 2012). Results indicated that users performed best when navigating a linear structure, but preferred it mostly because of the ability to go to the “Home” screen from any page since it allowed them to “start over”. However, paging between subsequent screens was actually found to be difficult, which contradicts our findings from the mobile phone experiments with low-literate users. This study though was conducted in a Western context with a higher literate group (with 10-14 years of formal education), half of who had previous experience playing computer games or browsing the internet occasionally.

Another closely relevant study (Kodagoda & Wong, 2008) identified that low-literate users spent eight times longer to complete a task when searching for social services information, visited eight times more web pages, back tracked thirteen times more, were four times more likely to revisit a web page, spent one third more time on a web page, and were thirteen times more likely to get lost or deviated from the optimal path. They developed Invisque, an electronic library resource discovery system, where information is represented by a two-dimensional spatial canvas, with each dimension representing user-defined semantics. Search results are presented as index cards, ordered in both dimensions. Intuitive interactions are used to perform tasks such as keyword searching, results browsing, categorizing, and linking to online resources such as Google and Twitter. (Wen, et.al. 2011). This study though was conducted in a Western context where study participants had to have computer and internet literacy (weekly computer and internet usage between four – ten hours.).

3.3.1 Hierarchical UI navigation among low-literate users in the developing world

While all of the above work is closely relevant to our research, most of this was done in the context of users with higher literacy than our target group and with greater exposure to ICTs. There are a handful of studies that have questioned the suitability of menu-based navigation for low-literate and novice users in the developing world context, though there are individual differences between each of these studies that we describe below (Jones & Marsden, 2005; Jones et.al., 2000; Katre, 2006). The first study (Jones and Marsden, 2005) presented a review of key interaction design ideas, techniques and successes, along with exercises, case studies and study questions for students. It critiqued current mobile interaction design to help designers avoid pitfalls, while defining design challenges and worked examples for low-literate and novice users. The second study (Jones et.al. 2000) questioned the suitability of menu-based navigation through various examples of web services on small screen mobile devices designed for the South African context. The third study (Katre, 2006) suggested reducing the use of abstract hierarchical structuring of information when doing instructional design for rural e-learning applications for low-literate users in India. However, all three of these studies were qualitative and anecdotal in nature.

The above leaves a gap for research studies that can provide experimental evidence to show how hierarchical UI navigation happens differently between low-literate and literate users. Our thesis research aims to fill in this gap by studying hierarchical UI navigation for low-literate users in the developing world, more specifically in India, having little or no education. We do this through controlled experimental studies in Chapter 4, and identify implications for the design of information architectures for low-literate users in Chapter 5. The research question that we investigate is:

Is hierarchical UI navigation difficult for low-literate users? If yes, in what way?

3.4 Research questions revisited

In the previous sections of this chapter, we looked at the theoretical underpinnings of transfer of learning, hierarchical UI navigation and research in cognitive science related to literacy. Given this, and anecdotal evidence from previous work in Text-Free UIs and DG described in chapter 2, the research questions that have emerged are:

- **Is transfer of learning in video-based skills training difficult for low-literate users? If yes, in what way?**
- **Is hierarchical UI navigation difficult for low-literate users? If yes, in what way?**

To answer the above, starting from our next chapter we do a systematic investigation of these questions and examine how the above are related to levels of literacy.

Chapter 4: Research design

In previous studies in Text-Free UIs and DG, we saw that there are many correlates of non-literacy. But we chose to focus on **transfer of learning in video-based skills training and hierarchical navigation** of ICTs, because of i) motivation from previous work in Text-Free UIs and Digital Green as discussed in Chapter 2 ‘Motivations’, ii) greater theoretical context, as described in Chapter 3 ‘Theoretical underpinnings’, and iii) greater design consequence.

Before moving onto our research hypotheses, we take a quick departure to describe our participant communities here:

4.1 Participant Communities

For our research we studied people from 5 low-income urban slum communities in Bangalore, India. Like in previous Text-Free UI research, we chose our participants from these communities because they fulfilled the criteria that we had for our study. They had (a) low levels of formal education (< Grade X); (b) no experience in using a computer.

One billion people worldwide live in slums (Davis, 2007) and the figure is projected to grow to 2 billion by 2030 (UN Habitat Report, 2007). A definition of a ‘slum’ has come to include the vast informal settlements found in cities in the developing world, in a run-down area of a city characterized by substandard housing and squalor and lacking in tenure security (UN Habitat Report 2007). In India alone, the total population living in slums was 65.5 million in 2011 (Ministry of Housing and Urban Poverty Alleviation), and is expected to grow to 107 million by 2017.

The communities we studied in Bangalore were from 5 areas: Raagiguda, Byrasandra, Sudarshan Layout, Nakalbande and Banashankari, located in the southern parts of the city. The study participants were recruited through intermediary organizations working in domains such as construction and informal domestic labour. One of the organizations, Stree Jagruti Samiti (<http://www.deccanherald.com/content/173609/campaigning-dignity-labour.html>, retrieved Sep 23, 2014) worked primarily with women involved in informal domestic labour. The other organization named LabourNet (<http://www.labournet.in/> retrieved August 24, 2012) was a

facilitating body between clients (contractors, end clients, construction firms, home owners, builders, etc.) and informal sector workers in construction, domestic labour, etc.

Each of the slum areas of our participant communities had about 100-300 households. The houses in these areas were generally made of low-cost building construction materials and had poor hygiene and sanitation conditions. The average area of a household was 150-200 sq. ft. There was poor infrastructure for sewerage and sanitation around the slum area. People had limited access to water supply from 2-3 shared municipal water taps per slum area. Water was available only during certain predetermined hours during the day.



Fig. 3a: Public water collection area



Fig. 3b: Alley inside the slum area



Fig. 3c: The inside of a living room



Fig. 3d: TV set inside a household

Most importantly, all of the people that we worked with had a number of commonalities. People in these communities had informal sector jobs: the female members of the household were domestic workers and the male members were daily wage labourers—plumbers, carpenters, construction workers, mechanics, bar benders, or fruit and vegetable vendors. They found these jobs through informal social networks like friends and family. Household income was between INR 3500- 7000 (approx. USD 58–115) per month. Nearly all the households in these communities had television sets, and over half of them had some video playback device (VCDs and DVDs). A large section of

men in the communities owned low-end limited functionality phones, although some Android phones were also becoming available among the younger population. Compared to men, relatively fewer women owned mobile phones. None of the people that we worked with had any previous experience using computers. Their primary language of communication was Kannada. Apart from this, people also spoke Tamil, Telugu, and Hindi. None of the people that we worked with had any working knowledge of English. Finally, people had low-levels of formal education. Highest education attained was Grade X in the K-12 education system. Many of the people that we studied had functional illiteracy: they were not able to read real-world print, e.g., road signs, bus schedules, etc. However, most people had some form of numeracy: were able to read up to 3-digit Indo-Arabic numerals e.g. 0,1,2,3, etc.

4.2 Transfer of learning in video-based skills training vis-a-vis levels of education

Our research questions in the previous chapter leads to our first hypothesis that skills required for transfer of learning in video-based training is correlated with levels of education, for our participant communities. *(This is based on using degree of textual literacy at the time of the experiment as the proxy for education, and we elaborate on this in the upcoming section 4.2.1).* We examined this relation by conducting an experiment, the goal of which was to understand the following:

- What is the degree of difference in cognitive skills required for transfer of learning in video-based skills training between users with little or no education and those with some basic education? (We define ‘little or no education’ and ‘some basic education’ later in the methodology section, based on a literacy assessment test).
- What is the degree of advantage for users with little or no education from generalized examples as a way to transfer?

4.2.1 Methodology:

- **Working definition of transfer of learning in video-based skills training:**

For the purposes of our study we define transfer of learning in video-based skills training as the ability to transfer learning from specific examples of a task demonstrated in instructional video to actual implementation in circumstances similar to (in attribute or relationship), but not necessarily identical to, that shown in the video. And as has been discussed in Chapter 3: Theoretical Underpinnings, this transfer can happen through the ability to reflect and abstract on attributes and relationships separate from the specific contexts of learning and application. Our study is done in the context of a “near transfer” learning task, discussed previously (Haskell, 2001).

Relevant to our study, *near transfer* has been described as when we transfer previous knowledge to new situations closely similar to, yet not identical to, initial situations. Transferring experiences associated with driving a car with a manual transmission to driving a truck with a manual transmission reflects an example of near procedural transfer (Calais, 2006).

- **Working definition of limited education**

Many studies in UI design and cognitive science, as has been pointed out in the research in the previous chapter (Theoretical underpinnings), use years of formal schooling as a measure for overall education level of a test participant. However, education level of an individual may not necessarily be correlated with the quantity of education measured in terms of number of years of schooling.

The overall education status of an individual could depend on a number of factors, which includes what school the individual attended, quality of teaching, role of parents and home environment, amount of effort invested, school attendance, nutrition conditions, genetics, etc. (Ernisch and Francesoni, 1997 and 2000; Becker 1993; Ernisch, 2000). However, these factors interact in multiple ways and their complex interaction is not fully understood, and in any case, separating and measuring the cause and effect of each of them accurately is impractical. Thus, we use degree of textual literacy – the ability to read and write – at the time of the study as a measure for overall quality of education of our study participants. (So ‘non-literate’ would mean somebody who is not able to read or write text.) It seems reasonable to take degree of literacy as a measure for quality of education, at least in modern societies where early formal education stresses textual literacy, and up to some level of education where there are differential levels of literacy. This is consistent with some cognitive science studies that use the textual literacy of individuals at the time of experiments

as the measure for education level (see, for example (Manly et.al, 2003; Reis et.al., 2001). The Reading Recognition subtest from the Wide Range Achievement Test – Version 3 (WRAT-3;Wilkinson, 1993) was used as an estimate of quality of education in the first study that examines memory decline among ethnically diverse elders (Manly et.al, 2003). This study suggested that textual literacy could be a more sensitive measure than years of education, because it more accurately reflects the quality of the educational experience at the time of testing. In addition, textual literacy could be a more accurate reflection of native ability because it does not assume that all individuals get the same amount of learning from a certain grade level. In the second study participants were categorized through a short reading/writing test, including word, sentence and text reading, test of reading comprehension, and word writing. (Reis et. al., 2001). It was found that non-literate participants performed significantly worse on immediate naming of two-dimensional representations of common everyday objects compared to literate participants, a skill that did not require reading-writing per se.

A review of existing worldwide assessment tools from the West [ALSA, n.d.; CASAS, n.d.; FAN, n.d.; NALD, n.d.; NAAL, n.d.; TABE, n.d.] did not reveal a suitable instrument to measure textual literacy for our participant community and we explain the reasons in more detail here. We suspected the level of the Western tools was too high for our target communities, and there was the added risk of conflation in translation from these tools. e.g. the most basic level for most of these tools required test takers to read isolated words, or in some cases even read narrative text in short sentences (in English), whereas in our target community there were some people who could not read beyond single alphabets (in their local language). Furthermore, the content was not always culturally appropriate: reading words were from Western food boxes, beverage labels, magazine ad inserts, etc. We then did a review of Indian literacy tools (NLM, n.d.; NSSO, n.d.). The Indian literacy tests were non-standardized as the assessment surveys did not have an objective way of measuring the literacy status of test takers. The protocol was for the investigator to ask if the test taker had attended school or not; if the test taker said that he/she did, the investigator would select a reading passage based on the his/her subjective judgment of the test taker's age, gender, general status, and background. The test taker was then asked to read the passage without any time limit. One or two questions were asked to judge the test taker's comprehension. To test 'writing ability', the test taker was asked to write a simple message or, alternatively, to write one or two simple

sentences dictated by the investigator from the passage. Based on the subjective assessment of reading-writing performance, the investigator categorized if the test taker was “literate” or “non-literate”.

Given this subjective nature of testing, we devised our own literacy assessment tool in consultation with an education researcher working in the area of primary education. The sections of the textual literacy assessment tool were designed based on our review of government school textbooks (Government of Karnataka Board of Education, 2008). The tool has limitations since its internal validity cannot be established statistically but it is the most closely relevant to all the options that were available to us. The tool consisted of three sections:

- 1) Reading—single words and phrases, simple full sentences, 3–4 sentence paragraphs (all in the local language Kannada);
- 2) Writing—single words and phrases, simple full sentences, correcting mistakes in paragraphs supplied (all in the local language Kannada); and
- 3) Numeracy—reading up to 3-digit Indo-Arabic numerals.

We did not assign numeric scores, but there was a pre-determined cut-off condition for passing the test. In other words, the participants did not receive any numeric scores, but they were categorized based on their performance with respect to the cut-off condition.

- 1) Reading cut-off: ability to read single words and up to short phrases (maintained at functional reading required for real-world print, e.g., road signs, bus schedules, etc.)
- 2) Writing cut-off: ability to write single words (maintained at functional writing for basic form-filling activities)
- 3) Numeracy cut-off: reading up to three-digit numbers written in Indo-Arabic numerals (maintained at functional numeracy for reading real-world print, e.g., bus numbers, price tags, etc.)

Training video

Participants in the experiment were randomly assigned to one of two types of instructional video, *specific* or *diversified*. Each video comprised a repetition of instructions (either identical or using a different technological appliance), so all participants were exposed to two sets of instructions prior to being tested.

- **Specific Video**

This video showed the use of one vacuum cleaner (Model 1) for all of tasks followed by a simple repetition of the same video. (We explain why we chose a vacuum cleaner for the technological appliance in the next section, ‘Experimental Task’). The length for the use of each part was 00:03:34 and the total length of the video was 00:07:08. The script of the video is provided in Appendix III. Fig.4 (a) and (b) have screenshots of the video.



(a)



(b)

Fig. 4 (a) Specific Video showing use of vacuum cleaner Model 1 in first half; (b) Specific Video showing repeat use of vacuum cleaner Model 1 in second half

- **Diversified Video**

This video showed the use of one vacuum cleaner (Model 1) for all tasks (the same as the first video above), followed by the use of a different vacuum cleaner (Model 2) for the same tasks. To maintain consistency with the Specific Video, both halves of this video were 00:03:34 and the total length was 00:07:08. The script of the video is provided in Appendix IV. Figure 5 (a) and (b) have screenshots of the video.



(a)



(b)

Fig. 5. (a) Diversified Video showing use of vacuum cleaner Model 1 in first half; (b) Diversified Video showing use of vacuum cleaner Model 2 in second half

- **Experimental task**

After watching a given video, study participants had to do experimental tasks on vacuum cleaners. We chose a vacuum-cleaning task for two reasons. First, study participants recruited from our

partner organization were *themselves* interested in learning to use vacuum cleaners to enhance their skill set for domestic labour. Thus, vacuum cleaning was relevant and motivating for our participants. Second, vacuum cleaners are available in different models, with minor variations for each function. This was appropriate for testing the “transfer” of learning from a specific vacuum cleaner to another model with analogous, but differing features. Any other task that met the two above criteria could have been chosen, as well.

- **Device familiarity**

Participants were tested on the various tasks using two different models of vacuum cleaner. Model 1 was the same appliance demonstrated in the video and was therefore *Familiar* to participants. In contrast, Model 3, was a new device, different than either Model 1 or Model 2 used in the videos. Model 3 was used to test the ability for abstracted learning on an *Unfamiliar* device. All models were selected such that the basic functions (tasks) were the same for the purpose of a fair comparative experiment. However the physical looks and the means to accomplish various functions were different. The order in which the different vacuum cleaners were tested was randomized to balance out learning effects across the two models: half of the participants were first tested on the *Familiar* device and the other half were first tested on the *Unfamiliar* device. Appendix V shows the order in which the videos were shown and the tests carried out. Table 1 gives details of the tasks on the *Familiar* Model 1 and the *Unfamiliar* Model 3. In the following paragraph we describe the different models of vacuum cleaners used in the study:



Fig. 6: Model 1, Model 2 and Model 3 used in the study

Model 1:

This was a bagged canister-style cleaner with the changeable dust bag inside of the canister. And a stick style floor nozzle port attached to the canister through a hose. It had a retractable cord that could be pulled out from an opening on the backside of the canister. To unwind the cord, the left

hand-side button on the lid of the canister needed to be pressed. There was a standard three-pin plug at the end of the cord. After plugging in the cord, the right hand-side button on the lid needed to be pressed to switch on/off the cleaner. There were two separate nozzle heads that could be replaced with the floor nozzle port; these were under the lid of the canister. They could be accessed by raising open the lid. To empty the dust a button under the front side of the canister needed to be pressed open to find the bag compartment. Inside of the compartment there was a changeable bag clipped on to a holder. The holder clip had to be pressed to release the bag. Fresh bags were available as separate accessories. Please refer to Table 1 for task-wise differences with Model 3.

Model 2:

This was a bagless model with an upright canister. The main intake port was attached to the canister at its bottom. The power cord was manually wound around the handle of the cleaner. There was a three pin plug at the end of the cord. After plugging in the cord, a button on top of the canister on the left side was to be pressed to switch on/off the cleaner. There was a separate stick style nozzle prefixed to the canister through a tube. To empty out the dust, a button on the right top side of the canister had to be pressed to release the canister from its housing. Thereafter the lid of the canister needed to be taken off, the canister emptied and the filter inside cleaned with a brush.

Model 3:

This model was used to test the ability for abstracted learning on a device not seen in the training video. It was a bagless canister-style model. There was a stick style lateral intake port attached to the canister through a tube. A retractable cord could be pulled out from an opening on the backside of the canister. A lever near this opening had to be pressed to rewind the cord back in. There was a standard three-pin plug at the end of the cord. After plugging in the cord, the button on one end of the handle of the canister needed to be pressed to switch on/off the cleaner. There were two separate nozzles in crevices on either side of the canister near the bottom. They could be slid out for use. To empty the dust, a buckle on the other end of the canister handle had to be pressed to release the canister from its housing. The filter could then be removed, the canister emptied and then the filter cleaned with a brush. Please refer to Table 1(a) for task-wise *similarities* and Table 1(b) for task-wise *differences* with Model 1.

Table 1(a): Task wise similarities between the two models of vacuum cleaners

Evaluation of Vacuum Cleaning (Familiar Model 1)	Evaluation of Vacuum Cleaning (Unfamiliar Model 3)
Pulling Out Cord from opening behind canister	Pulling out cord from opening behind canister
Plugging in the vacuum cleaner	Plugging in the vacuum cleaner
Inserting plug into wall socket	Inserting plug into wall socket
Turning on wall socket switch	Turning on wall socket switch
Turning on the vacuum cleaner	Turning on the vacuum cleaner
Pressing the button so that the VC turns on	Pressing the button so that the VC turns on
Positioning the vacuum cleaner at start	Positioning the vacuum cleaner at start
Positioning the VC squarely at one end of the rug	Positioning the VC squarely at one end of the rug
Vacuum in a straight line	Vacuum in a straight line
Pushing the VC forward to arms' length	Pushing the VC forward to arms' length
Pulling the VC back slowly	Pulling the VC back slowly
Reposition vacuum cleaner to vacuum parallel to area previously vacuumed so that the whole carpet is covered	Reposition vacuum cleaner to vacuum parallel to area previously vacuumed so that the whole carpet is covered
Moving the VC to the next part of the carpet correctly	Moving the VC to the next part of the carpet correctly
Extent to which full area of the carpet is covered	Extent to which full area of the carpet is covered
Use of attachments (upon instruction)	Use of attachments (upon instruction)
Fit on attachment	Fit on attachment
Correct use of VC with corner cleaning attachment	Correct use of VC with corner cleaning attachment
Switch off vacuum cleaner	Switch off vacuum cleaner
Pressing the button so that the VC turns off	Pressing the button so that the VC turns off
Unplug vacuum cleaner	Unplug vacuum cleaner
Switch off wall socket switch first	Switch off wall socket switch first
Unplug the VC cord gently	Unplug the VC cord gently

Table 1(b): Task wise differences between the two models of vacuum cleaners

Evaluation of Vacuum Cleaning (Familiar Model 1)	Evaluation of Vacuum Cleaning (Unfamiliar Model 3)
Turning on the vacuum cleaner	Turning on the vacuum cleaner
Locating the ON/OFF button (the right hand-side button on the lid)	Locating the ON/OFF button (button on one end of the handle of the canister)
Use of attachments (upon instruction)	Use of attachments (upon instruction)
Find attachment (under lid of canister)	Find attachment (in crevices on either side of the canister near the bottom)
Put back attachment (under lid of canister)	Put back attachment (in crevices on either side of the canister near the bottom)
Switch off vacuum cleaner	Switch off vacuum cleaner
Locating the ON/OFF button (the right hand-side button on the lid)	Locating the ON/OFF button (button on one end of the handle of the canister)
Wind up cord	Wind up cord
Push button (on left hand-side on the lid of the canister) to wind up cord	Push lever (near opening on backside of canister) to wind up cord
Cleaning bag	Cleaning container
Locate button (under the front side of the canister) to open lid	Locate button (on end of the canister handle) to slide canister

Press button to open lid	Release button to slide out canister
Pull out holder with bag	Remove filter from canister
Pull out bag from holder and throw away	Throw dirt from canister
Put new bag onto holder	Clean filter with brush
Slide holder into compartment	Fit filter back
Close lid	Slide canister into original position

- Study participants

We recruited participants based on their convenient accessibility and proximity to our partner organizations. The participants in this part of the study had low levels of formal education, <Grade X, with 79% of the participants with <Grade VIII education. A distribution of stated education levels of the participants is given below.

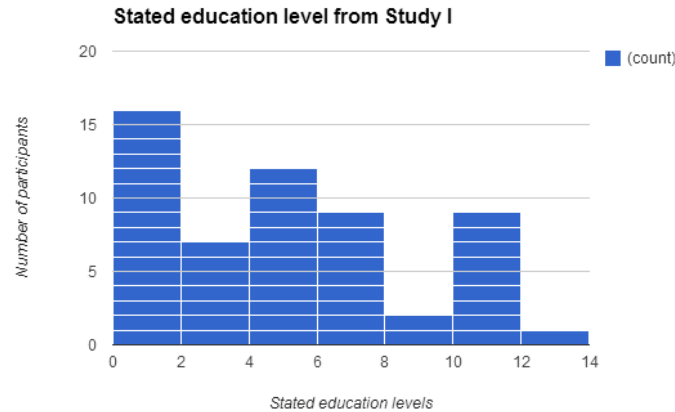


Fig. 7: Distribution of stated education levels

Their primary language of communication was Kannada. Apart from this, people also spoke Tamil, Telugu, and Hindi. Our literacy tool yielded two distinct groups in terms of the reading and writing sections; participants all either passed both the reading and writing tests, or failed both. We did not observe any borderline cases along the cut-off conditions for reading and writing. Participants who passed the test were categorized as “literate” or those with “some basic education”, while those who did not pass the test were categorized as “non-literate” or those with “little or no education”. One of the limitations of this tool was that it yielded only a binary classification of test participants and not a more granular categorization.

We worked with a total of 74 female participants, divided into groups representing each of the four between-subjects conditions (Education Level x Instructional Video). Because there were uneven numbers of participants in each cell, we randomly selected 14 participants from each condition to keep our experimental design balanced. This left us with a total of 56 participants: 28 in the “Literate” group, and 28 in the “Non-Literate” group (as per our literacy assessment tool). The average household income per month of the literate group was INR 4750 (USD 78), while the average for the non-literate group was INR 3850 (USD 63). Out of the 28 participants in the literate group, all 28 spoke Kannada, 21 spoke Tamil, 10 spoke Hindi, and 5 understood very Basic English. Out of the 28 participants in the non-literate group, all 28 spoke Kannada, 22 spoke Tamil, 11 spoke Hindi, and one person understood very Basic English. None of our participants had previous experience using vacuum cleaners, nor had they seen vacuum. In each Group (Literate and Non-Literate), 14 of the 28 participants watched the *Specific* instructional video, while the other 14 watched the *Diversified* video. Thus there were a four groups in the experimental procedures: Literate-Specific, Literate-Diversified, Non-Literate-Specific and Non-Literate Diversified. All participants were between the ages of 18 and 55 years. The mean and median of ages and stated education at the time of the experiment, and standard deviation across all four groups is given here:

Table 2: Mean and median of ages and stated education at the time of the experiment 1, and standard deviation across all four groups

	Stated education level			Age		
	mean	median	std dev	mean	median	std dev
Literate Specific	7.5	7.5	3.204564	28.71429	27	6.144774
Literate Diversified	5.928571	7	3.832338	30.85714	28.5	8.198097
Non-literate specific	1.357143	0	1.945691	29.42857	29.5	6.664652
Non-literate diversified	3.714286	5	2.233609	34.57143	35.5	9.460154

The difference between the Literate Specific group and Literate Diversified group in terms of age and stated education was not significant ($p=0.44$ and $p=0.24$ respectively). The difference between the Non-Literate Specific group and the Non-Literate Diversified group was also not significant in terms of age $p=0.108$. The difference between the Non-Literate Specific group and the Non-Literate Diversified group was significant in terms of stated education $p<0.006$. While there is a difference in stated education levels, but in practice the Non-Literate Diversified group participants

were not able to pass our literacy test. Which only reinforces that stated education level is not a good proxy for education level.

- **Experimental Design Overview**

As stated earlier, the 56 participants (Literate and Non-literate) were shown one of the two videos, *Specific* or *Diversified*. After viewing the training videos, all participants were tested on each of the tasks with two different vacuum cleaner models (*Familiar* and *Unfamiliar*) to test how much they learned from the videos. This yielded a 2 (Education Level) x 2 (Instructional Video) x 2 (Device Familiarity) mixed design.

- **Hypothesis revisited**

Our first hypothesis was that skills required for transfer of learning in video-based training is correlated with levels of education, for our participant communities. (*This is when we use degree of textual literacy at the time of the experiment as the proxy for education, described in section 4.2.1.*) We examined this relation by conducting an experiment, the goal of which was to understand the following:

- What is the degree of difference in cognitive skills required for transfer of learning in video-based skills training between users with little or no education and those with some basic education?
- What is the degree of advantage for users with little or no education from generalized examples as a way to transfer?

Based on earlier observations of participants with limited education from related work, and our own previous research in Text-Free UIs and trainings with DG, we expected to see non-literate participants (who did not pass the literacy test) performing significantly worse compared to literate participants on all experimental tasks. Second, we expected to see that of all combinations, *Specific* → *Unfamiliar* (which translates as watch *Specific* video, then perform task on *Unfamiliar* model) would be the most challenging as participants have to transfer learning from a specific example (videos of Model 1 alone) to an unfamiliar test device (Model 3). Furthermore, we expected that giving additional instructional examples (the diversified video) would assist participants in generalizing functionality beyond the specific example devices. As a result, we expected that

performance in *Diversified* → *Unfamiliar* (watch *Diversified*, then perform task on *Unfamiliar* model) would be better than *Specific* → *Unfamiliar*, because there would be more than one examples demonstrated to transfer from in the diversified video. We assumed that more than one examples helped with the process of transfer. A number of researchers in cognitive science studies have suggested that initial problem solving involves explicitly referring to examples (Anderson and Fincham, 1994; Novick and Holyoak, 1991; Pirolli, 1985; Ross and Kennedy, 1990). Sometimes these examples were available in a physical medium, like a textbook, or in other cases they had to be recalled from memory. In either case, the examples illustrate the solution of a problem, and the problem solver analogically maps the solution of an example, on to the solution of a current problem.

Note: In spite of the similarity in functions, Model 1 (Familiar) was a relatively difficult model to operate compared with Model 3 (Unfamiliar). Model 1 had a bag inside of the main body, attached under the lid, and changing this bag involved a number of steps. Whereas Model 3 just involved opening the canister with a single rotating action. **By assigning the relatively more difficult model as the familiar example and the easier model as the unfamiliar example, we were able to rigorously test for our expected result [the Specific → Unfamiliar (watch model 1 twice and perform tasks on model 3) combination as most challenging], without letting the complexity of the product itself impact results in a way that would have biased the experiment in favour of what we expected to observe.** Since this arrangement of models (Seeing model 1 and working on model 3) seems likely to work against the hypotheses (less abstracted learning required), if the hypotheses are borne out, we can be confident in the results.

- Data collection and documentation

Basic demographic information was collected for every test participant—name, age, level of schooling if any, occupation, languages spoken, etc.

The primary metric of success in testing was the amount and extent of assistance provided by the experimenter for each task; very little assistance is equated with more and better learning. Assistance was categorized by degree of intervention: simple encouragement, a spoken reminder and finally hands-on help provided by the experimenter. We stopped providing assistance (metric

threshold) when the study participant refused to proceed with the task any further. The assistance provided was consistent across all participants with words repeated verbatim for every participant, to control for motivational differences. We marked the different categories of prompts as escalation, but for the purpose of computation made no distinction in weight for any given intervention. In other words, every prompt received a score of 1. Figure 8 below shows a distribution of the number of prompts.

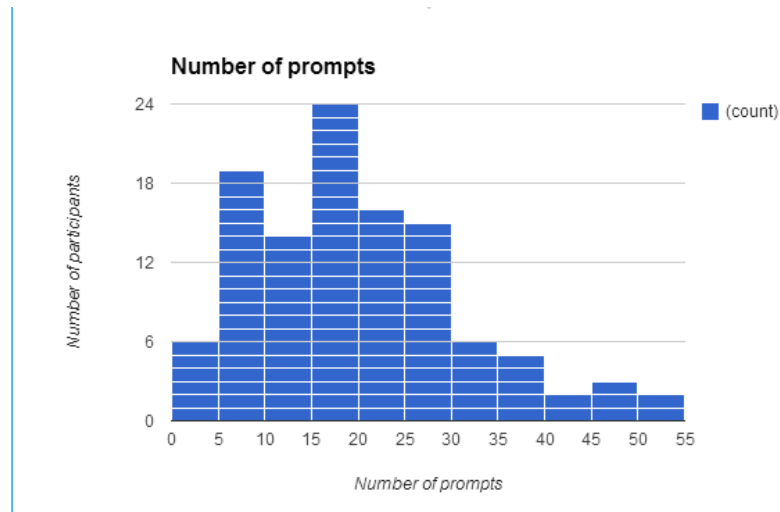


Fig. 8: Distribution of the number of prompts

In addition, all participants were video recorded by a videographer (different from the experimenter), as they performed each task and qualitative observations were made by the experimenter. We received informed consent from the participants prior to video recording them.

4.2.2 Results:

- Quantitative

For the overall analysis of performance on the vacuum cleaner tests, we performed a 2 (Education Level) x 2 (Instructional Video) x 2 (Familiarity of Device) mixed model ANOVA. Education level and Video type were between subjects factors and Familiarity was within subjects. The dependent measure of performance was the number of prompts by the experimenter that was required for participants to successfully complete the different tasks demonstrated in the instructional videos. Raw data from the study is in Appendix XV.

Figure 9 illustrates the mean number of prompts for each of the 8 cells. Overall, there are 3 main findings of particular interest (statistics are reported below). **First, literate participants required much less assistance than non-literate participants across the board. Second, participants had the most difficulty when they needed to transfer learning to an unfamiliar device. And third, literate participants appeared to benefit from diversified examples more than non-literate participants did.**

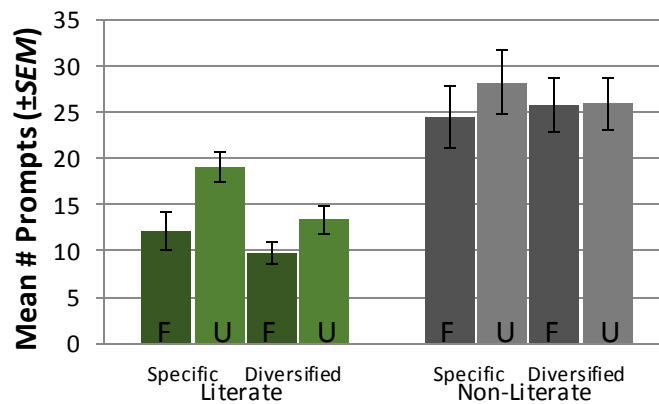


Fig. 9. Assistance required by participants to complete all tasks. Familiar and Unfamiliar devices are denoted as U and F.
(Numerical values for the graph)

	Literate	Non-Literate
Specific Familiar	12.14	24.5
Specific Unfamiliar	19	28.14
Diversified Familiar	9.78	25.78
Diversified Unfamiliar	13.35	25.85

Confirming our first hypothesis, literate participants required significantly less assistance than did non-literate participants, $F(1,52)=28.5$, $p<0.001$. In Fig.9, compare the left set of 4 bars to the right set. Across all conditions, literate participants required less than half as much assistance as non-literate participants (average of 11.6 vs. 26.1 prompts); they seemed to be much better at translating what they saw in the videos into actual practice.

Similarly there was a significant effect for Familiarity, $F(1,52)=14.4$, $p<0.001$. Not surprisingly, when participants were tested on the device they had seen in the video, they required less assistance

than when they needed to transfer the instructions to a new device (see the alternating dark vs. light bars in Fig. 9). The main effect of Video was not significant ($F(1,52)=0.923$, $p=0.34$).

While no interactions were significant, two were borderline, trending towards significance. First, there was a trend for Education $\times$ Familiarity, $F(1,52)=3.24$, $p<0.078$. Figure 9 suggests that the effect of Familiarity was stronger for literate participants than for non-literate participants. For non-literate participants, performance was about the same whether the device they used was in the video or not ($t(54)=0.59$, $p=0.56$).

Second, there was a trend for the interaction of Video $\times$ Familiarity, $F(1,52)=3.38$, $p<0.072$. While this was not quite significant, it does lend some support to our second hypothesis: giving additional instructional examples (in the diversified video) did seem to help participants perform better with the unfamiliar device. In Figure 9, comparing the first two bars to the second two bars in each group suggests a larger effect of Familiarity when participants saw specific videos than diversified videos (with more than one example), though this is much more obvious for literate than non-literate participants.

In fact, Figure 9 suggests that our various manipulations in abstractions had no statistically significant effect on the assistance required by our non-literate participants (ranging between 24.5 and 28 average prompts); they appeared to have difficulty moving from the instructional video to physically reproducing what they had seen, irrespective of the amount of generalization required. In contrast, the manipulations of *Instructional Video* and *Familiarity* influenced our literate participants much more. These participants were very good at directly matching what they saw on the screen to physical activity (*Familiar* devices for either video type), but they particularly benefitted from the additional generalization provided by the diversified video for both devices they used (see Figure 10). For both *Familiar* and *Unfamiliar* tests, the diversified video appeared to reduce the amount of assistance needed by our literate participants. As we might expect, this is largest for the *Unfamiliar* device ($M=19.0$ and 13.4 respectively for specific and diversified video, $t(14)=2.56$, $p<0.017$). In other words, 30% less assistance needed.

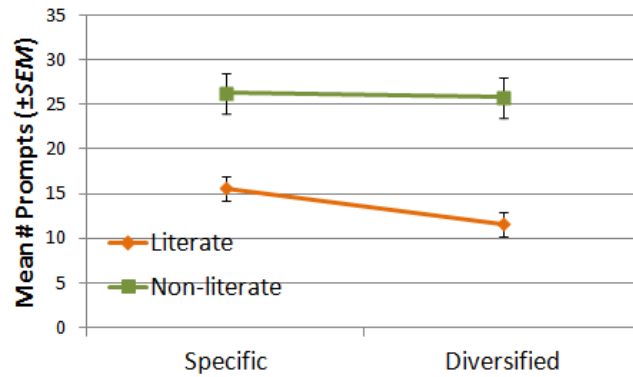


Fig. 10. Literate participants showed a marginal advantage compared to non-literate participants when help was provided through diversified content.

- Qualitative observations and discussion

Throughout our formal study, we also made a number of informal qualitative observations. We discuss them here, because they provide additional context and point toward our next study and similar future studies.

Our experimental study showed that literate participants appeared to benefit from diversified examples more than non-literate participants did. In the case of literate participants, the diversified video appeared to reduce the amount of assistance needed. Whereas in the case of the non-literate participants the improvement due to the diversified examples was non-significant. We suspect that seeing more than one example in the video was cognitive overload for some non-literate participants. Model 2 was shown in the video but was not used in the tasks, yet the instructions shown had to be retained in memory should participants be actually tested on that model. This could have been confusing to some of the non-literate participants. As one of our non-literate participants later noted, “I watched 2 cleaners in the video (Model 1 and 2). It was a lot to remember. I used 2 cleaners (in practice). But one of the cleaners in the video was not given for use (Model 2 not given for actual use)”. These observations suggest that there might be limitations on the kind of examples that are demonstrated in an instructional video for non-literate participants and we elaborate on this in the discussion in Chapter 5.

Other than this, overall, we observed that for both the literate and the non-literate participants, within every task, people who were younger (<30 years old) were more attentive while watching the videos e.g. body leaning into the monitor, etc. They seemed more confident and went about

doing the tasks in a brisk manner. Older participants (>45 years old), usually needed more encouragement for both getting started on the task and for task completion. If they were unable to do a task the first time around, they would look in the direction of the experimenter and pause, expecting prompting before trying the task another time. We *suspect* this might have happened because of either of two reasons—first, this could be due to low confidence levels, especially on a piece of technology new to them. More interestingly, this may be related in some way to the difference in the power distance between the study participants and experimenters, which older participants seemed to be more conscious of. Because of an implicit class hierarchy, our older participants might have feared that they would be taken to task if something happened to the vacuum cleaner—if they broke or spoiled it. It may be that they looked in the direction of the experimenter expecting reassurance that everything in fact was going on okay.

There were a number of vacuum cleaning functions that we tested participants for. Some of these functions had fewer similarities between the examples in the videos and the test device. Overall, we expected to see functions with more similarities transferred relatively easily compared to functions with fewer similarities. During the experiment, we observed that both literate and non-literate participants seemed to require less assistance for accomplishing functions with more similarities (e.g. plugging the vacuum cleaner to the switchboard, turning on/off) compared to functions with fewer similarities (e.g. changing bag to throw out dust in one vacuum and cleaning the canister to empty dust in another vacuum cleaner).

One thing is worth noting in the results section: Given our choice of a sampling method, we caution our readers against generalizing the results of this study to every low-literate person across the world, but there are grounds to suspect that much of our observations will transfer to other similar groups with little or no education, at least within India, if not to other developing countries with a similar educational context and socio-cultural ethos.

4.2.3 Summing up:

In this study our hypothesis is proved **that skills required for transfer of learning in video-based training are in fact correlated with levels of education.** (*This was based on using degree of textual literacy at the time of the experiment as the proxy for education*). We confirmed a degree

of difference in cognitive skills required for transfer of learning between ‘non-literate’ and ‘literate’ users in video-based skills training. Users with some basic education required less than half as much assistance as users with little or no education on all transfer tasks. We also showed that users with little or no education did not benefit from generalized examples in a training video as a way to learn abstract concepts, as much as participants with some basic education did. For people with some basic education, seeing a generalized example led to 30% less assistance required to transfer learning to a device not seen in the video. An ability for abstraction seems to be an important cognitive skill for effective transfer of learning to help identify common attributes that the training video and the real-world tasks share, and to adapt to different attributes. Related literature also has discussed how transfer sometimes depends on whether learners have abstracted critical attributes of a situation (Gick and Holyoak, 1980, 1983; Bates and Holton, 2004). Transfer of learning in our video-based skills study could not have occurred had there not been some abstract reasoning involved in identifying common attributes. Based on this we realized that going forward, measuring abstract reasoning skills would also be important, in addition to literacy levels.

4.3 Hierarchical UI navigation vis-à-vis levels of education

As discussed earlier, in addition to transfer of learning in video-based skills training, we also chose to focus on hierarchical navigation of ICTs among users with limited education. **Our research questions in the previous chapter leads to our second hypothesis that skills required for navigation of hierarchical UIs is correlated with levels of education, even when the UIs are Text-Free.** (*This again is based on using degree of textual literacy at the time of the experiment as the proxy for education, like in the previous experiment.*) We examined this relation by conducting an experiment, the goal of which was to understand the following:

- To what degree are education levels and ability for abstract reasoning predictive of performance in navigating UI hierarchies? (Based on observations in Study I, we realized measuring abstract reasoning skills would also be important, in addition to education levels. We define ‘education levels’ and ‘abstract reasoning’ later in the methodology section).
- To what degree is education level correlated with ability for abstract reasoning?

Based on these questions, going forward we would measure three entities: a) education level, b) abstract reasoning and c) ability to navigate UI hierarchies. We describe how we define and measure each of these entities in the next section.

Looking at the first experiment and anecdotal evidence from previous and related studies we expected to see participants with higher literacy levels do better on the test for abstract reasoning, than those with low literacy levels. We expected a *positive correlation* between abstract reasoning and literacy test scores. Also we expected the test participants with low literacy scores or low abstract reasoning scores, to do significantly worse on the deep hierarchy UI, than those with high literacy scores or high abstract reasoning scores. Overall, we expected to see the following patterns:

- 1) Performance on navigating hierarchies is related to literacy score.
- 2) Performance on navigating hierarchies is also related to abstract reasoning score.
- 3) Literacy scores are correlated with measurements of abstract reasoning.

4.3.1 Methodology:

- Testing for educational level

Consistent with the first experiment we used degree of textual literacy – the ability to read and write – at the time of the study as a measure for overall quality of education of our study participants.

We have seen from Figure 8 in the previous study that the number of prompts required to do the tasks were normally distributed among 56 participants, which probably means that literacy is a gradient.

But the instrument in our first experiment allowed for only a binary classification of test takers ‘literate’ and ‘non-literate’, and hence it was inadequate. We did not want use this instrument going forward. Instead we wanted a tool that would allow for more granular assessment of literacy and greater nuance, than the first experiment, in observations for performance in navigation of UIs.

We devised a new textual literacy scale by borrowing content from standard local language government school textbooks, from grades I, III, V and VII (Government of Karnataka Board of Education, 2008); with the scale corresponding to the ability to understand textbook content of increasing grade level. We referred back to the *first experiment* and found that 79% of the participants there had < Grade VIII education (refer to Figure 7). Hence grade VII was considered to be the highest level of difficulty for the literacy assessment tool for this current experiment.

The grades were taken as the points of reference for the different values on our literacy scale. The content from the textbooks was borrowed in consultation with an education researcher working in the area of primary education. The increasing levels of difficulty on our literacy scale corresponded to the increasing level of grade from whose textbook content was borrowed: Level 0 corresponded to non-literacy; level 1 corresponded to grade I content, level 2 to grade III, level 3 to grade V and level 4 to grade VII. Expectations of the textual literacy scale and an overview of the content are summarized in Table 3. The test questions were picked such that there was sufficient distance between successive levels e.g. Reading letters and words for level 1, and passages for level 2; writing letters and words for level 1, and sentences and paragraphs for level 2. This was also the reason why we skipped content from grades II, IV and VI, so there was clear distance between the levels. Detailed test instruments are in Appendix VI.

Every level had two sections: reading and writing. We did not include a numeracy section on this test, because even non-literate people in our participant communities (as has been discussed earlier, knew how to read numerals). A numerical scoring system was devised for the purpose of grading participants. The total marks allotted for each level was 50 (25 for reading and 25 for writing).

Table 3. Textual literacy assessment scale showing category of questions along with allotted marks

Reading			Writing (Dictation)		
First Standard					
Identify Letter	10 X 0.5	5	Write Single letters	5 X 1	5
Identify simple 2 or 3 letters words	10 X 1	10	Simple 2/3 lettered words	8 X 1.5	12
Read Sentences	5 X 2	10	See picture & write the word	4 X 2	8
		25			25
Third Standard					
Simple sentences	3 X 1	3	Simple words 3/4 lettered	4 X 1	4
Hard Sentences	3 X 2	6	Hard words (Othakshara) 2/3 lettered	3 X 2	6
Passage Reading - 6 sentences (Page 21 of III Text)		6	Simple sentences	5 X 3	15
Para Reading 5 marks, each Q&A 2.5 marks	5 + 5	10			
		25			25
Fifth Standard					
Comprehension - I 5 marks + 3 Q&A - 5 marks (1+2+2) (Page 21 of v text)	5 + 5	10	Simple Sentences	3 X 2	6
Comprehension - II Poem - Stanza 1,2,3,5 (16 lines) 16 X 0.05 marks	16 X 0.5	8	Hard Sentences	3 X 3	9
Q & A based on the poem Q-1,2,3 - 2 marks each Q 4 - 1 mark	2 X 3=6 1 X1=1 6+1 = 7	7	Reading Q&A on the para - 2 Q&A - 2.5marks each	2 X 2.5	5
			Grammar - Writing Plurals	5 X 1	5
		25			25
Seventh Standard					
Comprehension (Abstract) Reading - 4 marks 2 Q&A on this para - 3 marks each = 3 X 2 = 6	4 + 6	10	Q&A on comprehension	2 X 2.5	5
Comprehension Reading - 5 marks 5 Q&A - 2 marks	5 + 10	15	Write the correct opposite word	5 X 2	10
			Make sentences	5 X 2	10
		25			25

- ***Process of administering and scoring the test***

Test participants were first administered the test corresponding to their reported years of formal schooling, e.g. Level 3 (grade V content) for a participant with grade V or grade VI formal education. Depending on their performance on a test, some participants received follow-up tests. If the participant made no progress on the initial 3 items of a test in spite of probing from the experimenter, that test level was discontinued and the test from the level just below it was administered {e.g. in this case Level 2 (grade III content)}. If the participant correctly answered 90% of the test questions, the test above it in level was to be administered (though this event did not happen in practice). There was no time limit to complete the test, though in practice, no participants took longer than 40 minutes.

Literacy scores were then computed as follows: For each participant, the highest test for which a participant was able to complete some but not all of the test was chosen. Fifty points were then added for each test level below the corresponding test. (Thus, someone who partially completed a Level 2 test was given a starting score of 50.) Then, the score on the test (between 0-50) was added. We maintained this procedure consistently across this literacy test. So scoring on the scale looked like this:

Table 4. Scoring on the textual literacy assessment scale

Level 0 (Non-Literacy)
Level 1 (Grade I) +0
Level 2 (Grade III) +50
Level 3 (Grade V) +100
Level 4 (Grade VII) +150

Final scores ranged from 0 to 200, with no overlap of scores among levels. The different literacy levels, with the literacy scores and weighted literacy scores that were yielded from our assessment of 60 test participants is provided in Appendix XIII.

Now that we are done defining education levels, we move on to defining our next entity: abstract reasoning.

- **Testing for abstract reasoning**

Like previously mentioned, based on the first experiment we realized measuring abstract reasoning skills would also be important, in addition to education levels. Our search yielded a number of tests for reasoning that we eventually rejected: the California Proverb's Test (Gorham, 1956), the Mednick's Remote Associates test (Mednick, 1962), Draw a Person Test (Goodenough, 1926) and Duncker's Candle Test (Duncker, 1945). These tests had the following problems from the perspective of our research: a) the California Proverbs' test and the Mednick's Remote Associates test were not neutral to formal education (e.g., assumed literacy). Test takers had to be able to read to take these tests, b) The Duncker's candle test was not standardized, therefore performance of test takers could not be ranked; and c) the Draw a Person test was aimed at understanding children's cognitive development. Details about each test in Appendix VII.

We then considered the Raven's Progressive Matrices as it was a literacy-independent test. We started with a review of related literature. The first paper (Brouwers Vijver, & Van Hemert, 2009) described a cross-cultural and historical meta-analysis of Raven's Progressive Matrices. Data were analysed of 798 samples from 45 countries ($N = 244,316$), which were published between 1944 and 2003. Country-level indicators of educational permeation, the samples' educational age, and publication year were all independently related to performance on Raven's matrices. The second paper (Irwing & Lynn, 2005) was a meta-analysis of 22 studies of sex differences in university students of means and variances on the Progressive Matrices. The results disconfirmed the frequent assertion that there is no sex difference in the mean but that males have greater variability. Results from the third paper (Rushton et.al., 2004) implied that scores on the Raven's Matrices are as valid for Africans as they are for non-Africans. This study was done by examining data from 306 highly select engineering students in a South African university. Given the Raven's Progressive Matrices (Raven, 1936; Raven 1981) was highly cited and validated in psychology literature, and was also a literacy-independent test, we used the same for measuring abstract reasoning.

The Raven's Progressive Matrices test was composed of non-verbal multiple choice measures: in each test item, the participant had to identify the missing element that completed a pattern. The standard version of the test had 60 questions that needed to be completed in 40 minutes. Informal pilot tests showed that our participants steadily became tired and impatient over the course of the

test perhaps because our participant community is not generally exposed to such prolonged testing scenarios. Given this might affect test performance we pick a widely-used adapted version of Raven's Progressive Matrices for final testing. This adapted version of the standard test consisted of 18 patterns in the form of a 3x3 matrix (Ego pont), refer Figure 11.

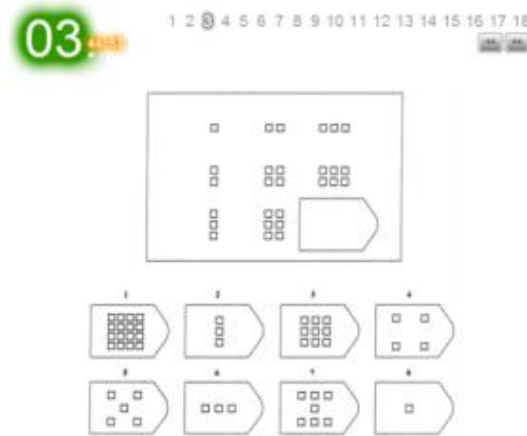


Fig. 11. Item 3 of Ego pont's Raven's test

Process of administering the Raven's test

Test participants were first shown 3 Raven's matrices questions, each of whose solution was demonstrated by the experimenter. The demonstration of the test was done in the local language of the test taker, e.g. Kannada and Tamil. Then, they were given 20 minutes to solve 15 additional Raven's matrices questions on their own. The duration of 20 minutes was established through informal trial tests discussed earlier. Each correct response would fetch 1 point totalling up to 15 points for all correct responses.

In this subsection we defined and discussed how we measured abstract reasoning for our experimental study. Going forward we define and discuss the third and final entity of this study: hierarchical UI navigation.

- Hierarchical UI navigation

Computer interfaces have largely depended on hierarchical information architectures for presentation of information. Virtually every website or application that has more than a few pages

uses a hierarchical structure for organizing content, to reduce the use of screen space. Pages are categorized into groups, often with distinct subgroups and the end result is a hierarchy of content.

There is precursor to work in hierarchical information architectures from early work in cognition and categorization. Rosch et.al. 1976 argued that within taxonomies of objects, categories are structured such that there is generally one level of abstraction at which the most basic category cuts can be made. A category consists of a number of objects that are considered equivalent. A taxonomy is a system by which categories are related to one another by means of class inclusion. The greater the inclusiveness of a category within a taxonomy, the higher the level of abstraction. Our work also deals with a hierarchical categorization of objects, but the way it would be different is that Rosch's study was for natural objects, whereas in our experiment we chose manmade objects, and we discuss this in the following paragraphs. This could be a potential limitation of our study, but we hoped much of the principles of cognition and categorization would transfer to manmade objects as well.

To test for the ability for hierarchical UI navigation we needed UI prototypes that would help measure participants' abilities. For a start we looked for a domain that met the following criteria: a) allowed for test items to be represented graphically, since we were working with a limited education population; b) was widely understood and did not require any domain specific knowledge; c) was gender neutral; and d) would allow for extensive categorization. After considering various domains such as health disorders, agricultural tools, railway reservations, we finally chose commonly used household items (by our target communities) as the domain for design, e.g., items of clothing, jewellery, utensils, electronics, games and sports, etc. A total of 40 common household items were selected for the prototype design. Going by our own previous research (Medhi et. al., 2007), we used photographs to represent each of these items since information representation required specificity. The test was for finding and identifying items; identification required that an item be represented as specifically as possible. Hence we chose photographs as the medium to depict information on the UIs for this study. Each of these UI prototypes were displayed on a Tablet PC Lenovo X200, screen size measuring 11.6 x 10.1 inches.



Fig. 12. Tablet PC Lenovo X200

We considered three organizations in increasing order of IA hierarchy depth:

- A list UI of 40 items, organized in a total of 5 rows. There were from 7 to 9 items in every row. If the number of items in one category (of the household items) exceeded the number of items that could be accommodated on a row (>9 items), they followed in the next row. The next category of household items began from the same row where the previous category ended. Overall, a total of 40 items were visible all at one on the Tablet PC screen. To select any item, the test participant had to point to the item with the stylus. See Figure 13. A detailed position map of the list UI (in text) is given in Appendix VIII.



Fig. 13. List UI organization page

- A shallow hierarchy UI of 40 items (2 levels deep with average branching factor of 8)

The items here were organized in a top-down navigation tree based on two levels of organization: first level is the item category (e.g. Clothes, electronics, jewellery, etc.), and second level is the type of item (Shirt, TV set, bangles, etc.) Please refer to Figure 14 for the Information Architecture details. On the UI, each node of the organization was represented by a photograph that best depicted that node, based on informal trials with members of our target community e.g. an assortment of randomly selected items of electronics, jewellery, utensils, to represent item categories of “electronics”, “jewellery”, “utensils”, respectively; the photograph of these items were bound within the image of a rectangular box.

- A deep hierarchy UI of 40 items (4 levels deep and average branching factor of 3).

The items here were organized in a top-down navigation tree based on four levels of organization: first level is how the item is used (e.g. things you wear, things you use), second level is item category (e.g. Clothes, electronics, jewellery, etc.), third level is item sub-category (Men’s clothes, living room electronics, hands jewellery, etc.) and fourth level is type of item (Shirt, TV set, bangles, etc.). Figure 14 shows the IAs of the shallow and deep hierarchies. On the UI, each node of the organization was represented by a photograph that best depicted that node, based on feedback from informal trials with members of our target community. The labels are based on terminologies used in India by our participant communities.

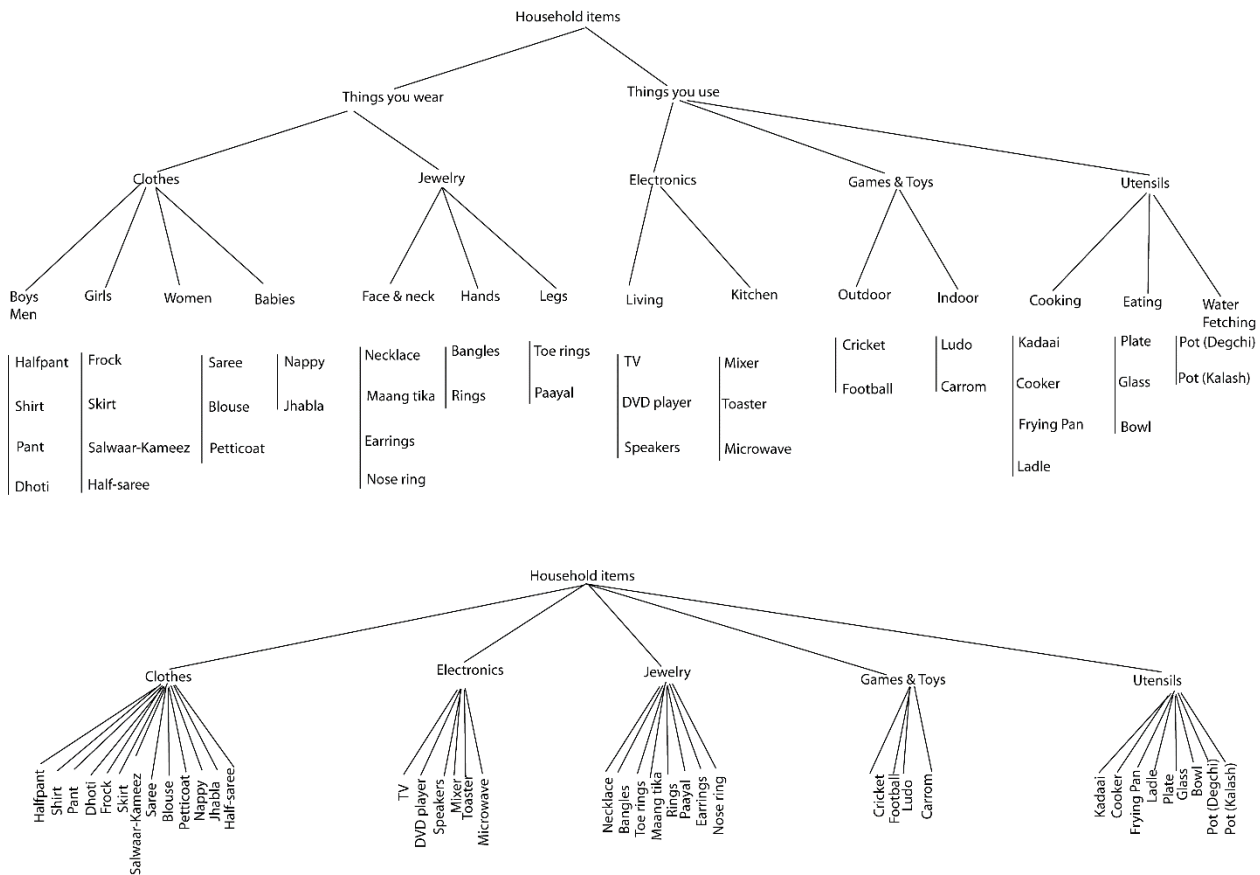


Fig. 14: Deep UI architecture, (above): shallow UI architecture (below).

To select any given item, test participants had to make two choices down the navigation tree in the shallow hierarchy and four choices in the deep hierarchy. The interfaces were completely graphical with no text. Clicking with the stylus on a certain graphic would take the user to the next level (sub-ordinate categories) of the hierarchy. There was the provision to go back to the previous page in the hierarchy by clicking on a “back” button at the bottom right corner on any given page (Figure 15).



Fig. 15: Screenshot of a page from the deep hierarchy UI

To ensure that there were no cultural or other differences between our categorizations and the categorizations that might be understood by our participant community, we conducted an informal pilot test for validation with 8 people (4 male, 4 female, with formal education between Grade V-XII). Forty printed cards were presented to each participant; each card contained one household item each from the IAs. The task for the participants was to group the items into categories, and then group those categories, until they reached a point where all items were in one set. Since this was an informal test, we did not maintain a score of timings or assistance required. Though overall, the categorizations that our participants created were consistent with our designs, e.g. ‘men’s clothes’, ‘women’s clothes’, ‘jewellery’, ‘kitchen electronics’, ‘cooking utensils’, etc. Out of the 4 female participants, 3 were not able to group the ‘games and sports’ category of items. Out of the 4 male participants, 3 were not able to group the subcategories of ‘face and neck jewellery’, ‘hands jewellery’ and ‘feet jewellery’. We should also note that 5 of the 8 people could not make it all the way until they reached a point where 40 items were in one set. The 3 people who could group all the way had completed formal education between Grade X-XII.



Fig. 16: Participant categorizing printed cards

Process of administering the UI test

Every participant was randomly allotted any one of the prototypes (list / shallow hierarchy / deep hierarchy). They were asked to carry out five tasks: each task required them to find a given household item on the UI that was allotted—a set of bangles, water pot, a football, a pair of shorts and a mixer-grinder. There was a time limit of 2 minutes for every task. We used the timing in the UI test solely as a mechanism for making progress with participants; the fact that participants were timed was not announced to them. Thus, participants did not perceive that they were under time pressure – what they experienced was that occasionally, we would simply move onto another task. As such, we do not believe the time limit negatively impacted our UI test results. Consecutive tasks

were announced only after the previous task was over. There was a standard script of verbal instructions provided at the beginning of the test by the experimenter, provided in Appendix IX.

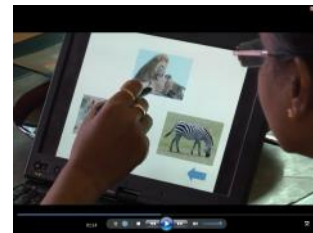
Before using the UI prototype, for both the deep and the shallow hierarchy, participants watched a 2 minute 5 second instructional video on how to use the UI on the Tablet PC. Refer Figure 17. Participants could watch the video as many times as they wanted, up to a maximum of three times. The instructional video had details on how to hold the stylus; how to hover and click; and explained the concept of nesting. Refer Appendix X for the script of the video. (There was no video shown before use of the list UI, since it did not contain nesting or require hover and clicks. Participants were only required to *point* to the requested items with the stylus, as the screen was non-reactive to press and pressing with stylus would not lead to any action. How to hold the stylus was demonstrated in-person. We recognize that the instructional video not being a constant between the hierarchies and the list UI design could be a potential limitation of the study). The domain for the instructional video was animals-birds kingdom instead of household items, so there was no learning effect on the actual tests. There was no assistance provided by the experimenter during use of the UI.



Introducing the instructional video



Explaining hover and clicking with stylus



Explaining the concept of nesting

Fig. 17: Screenshots of instructional video shown before use of deep and shallow hierarchies

- Participants

Like the first experiment we recruited participants based on their convenient accessibility and proximity to our partner organizations. All 60 test participants for the experiments were drawn from the same communities as study I. Fulfilling our primary criteria, all of these participants had less than Grade X education and did not have any previous experience using computers. For other details please refer back to the beginning of this chapter in the section ‘Participant Communities’ in section 4.1.

- Experimental Procedure

60 participants were recruited for the study. Attempts were made to involve a diverse group across age and gender.

For consistency, the same researcher acted as experimenter for all participants and followed a fixed script. The researcher first gathered information about the participant such as their age, years of formal schooling, and technology usage. Then, each participant took each of the literacy test, the Raven's test, and one version of the UI test.

We conducted a 3x3 between-subjects experiment design. There were 3 kinds of UI prototypes – list, shallow hierarchy, and deep hierarchy. Based solely on our literacy test, the 60 test participants fell into the following bins:

Table 5. Literacy bins for the 60 test participants

Literacy levels	Level 0	Level 1	Level 2	Level 3	Level 4
No. of participants	14	6	11	9	20

These 5 levels of literacy above were collapsed into 3 groups– low literacy (level 0-1), medium literacy (level 2-3), and high literacy (level 4), based on the frequency of occurrence of scores on the literacy test. This created roughly equal sized groups. Thus, there were a total of 9 experimental conditions. Each condition for the deep and shallow hierarchies had 7 test participants, and list had 6 participants each. The experimental design is illustrated in Table 6, together with total number of participants per condition, gender break-up, mean and median ages and SD. Through a single-factor ANOVA we observe that there is no statistical difference between the 9 groups in terms of age $F(8,51)=0.46$, $p=0.87$. Though in general we saw that the more literate participants in our target communities tended to be younger. This is likely due to the increase in school enrolment and quality of education in recent years, owing to the Government of India's efforts towards universal elementary education (Sarvashiksha Abhiyaan).

Table 6. 3X3 experimental design with nos. of participants (m=male, f=female)

	Low literacy (Level 0-1) Total nos. m+f mean, median age, SD	Medium literacy (Level 2-3) Total nos. m+f, mean, median age, SD	High Literacy (Level 4) Total nos. m+f, mean, median age, SD
Deep	7, 4+3 38 yrs, 36 yrs, 11.95	7, 4+3 33.4 yrs, 26 yrs, 17.25	7, 4+3 30 yrs, 23 yrs, 15.75
Shallow	7, 4+3 38.2 yrs, 42 yrs, 13.82	7, 3+4 34 yrs, 28 yrs, 15.18	7, 4+3 30.5 yrs, 23 yrs, 14.79
List	6, 3+3 38.8 yrs, 35 yrs, 16.05	6, 3+3 41.6 yrs, 41 yrs, 15.35	6, 3+3 34 yrs, 32.5 yrs, 13.08

Experimental Variables

The variables that we measured are as follows:

- Literacy test score (on maximum 200)
- Raven's test score (on maximum 15)
- UI test: Number of tasks performed correctly (maximum 5), Total time taken for tasks performed correctly, Total time taken (maximum 10 minutes for tasks performed correctly and incorrectly).

- Documentation

To make the process of experimentation less intrusive, we did not video record the user tests. We collected notes in situ on paper and timed the UI prototype and Raven's test use. Select photographs of the test participants and testing environment were also taken. There was 1 experimenter and 1 additional scribe for note-taking. The test were done in a community maintained slum development office located within one of the slum areas where we worked.



Fig. 18: Participant taking the UI test

- **Data analysis**

Grouping of participants

For the purpose of data analysis, participants were divided into three groups based on the frequency of occurrence of scores on the literacy test (as mentioned earlier) and on the Raven's test as Low, Medium and High in each category.

For Raven's test:

- "Low abstract thinking" (score 0-2) (20 participants)
- "Medium abstract thinking" (score 3-5) (25 participants)
- "High abstract thinking" (score 6-n) (15 participants)

For literacy, summary of details here for easy reference:

- "Low literacy" (score 0-50) (20 participants)
- "Medium literacy" (score 51-150) (20 participants)
- "High literacy" (score 150-200) (20 participants)

4.3.2 Results

- **Quantitative**

Confirming our hypothesis, increases in literacy test scores were correlated with increases in abstract reasoning test scores. Spearman's Correlation of the Raven's vs Literacy scores showed the correlation is significant with $\rho = 0.706$ at $p < 0.0005$. Raw data from this experiment is in Appendix XIII.

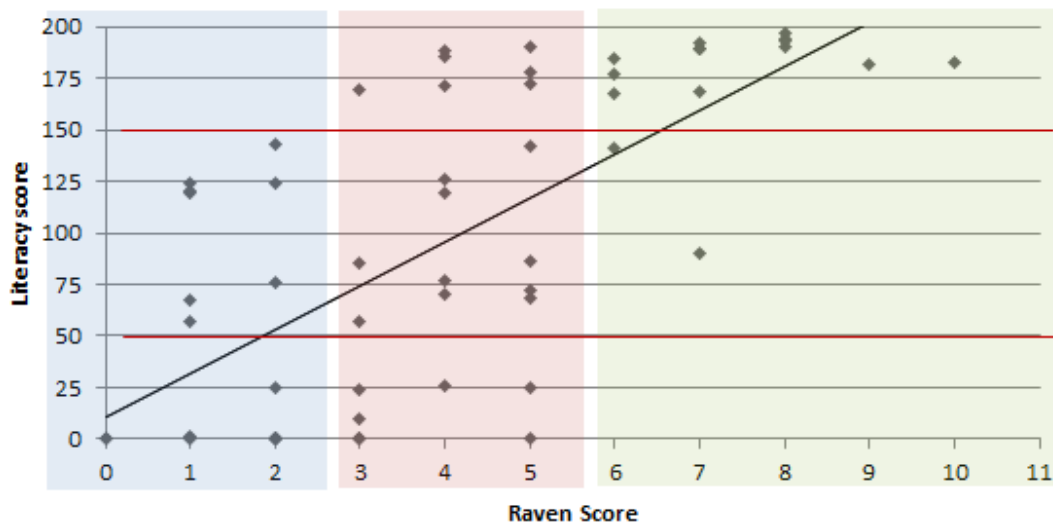


Fig. 19: Scatter plot for Raven's score-Literacy score

Correlations

		Ravens	Literacy
Spearman's rho	Correlation Coefficient	1.000	.706**
	Ravens Sig. (2-tailed)	.	.000
	N	60	60
	Correlation Coefficient	.706**	1.000
	Literacy Sig. (2-tailed)	.000	.
	N	60	60

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

Figure 20a on next page illustrates the mean time taken for correct responses for each of the nine cells for the literacy groups. There are two main findings that are of particular interest. Confirming our second sub-hypothesis, participants with “high” literacy required significantly less time to navigate the deep hierarchy, than groups of participants with “low” literacy (average of 64 vs. 104 seconds) $t(12)=3.81$, $p<0.01$ (i.e. 38.4% less time), as well as those with “medium” literacy (average of 64 vs. 101 seconds), $t(12)=3.26$, $p<0.01$ (i.e.36.6% less time).

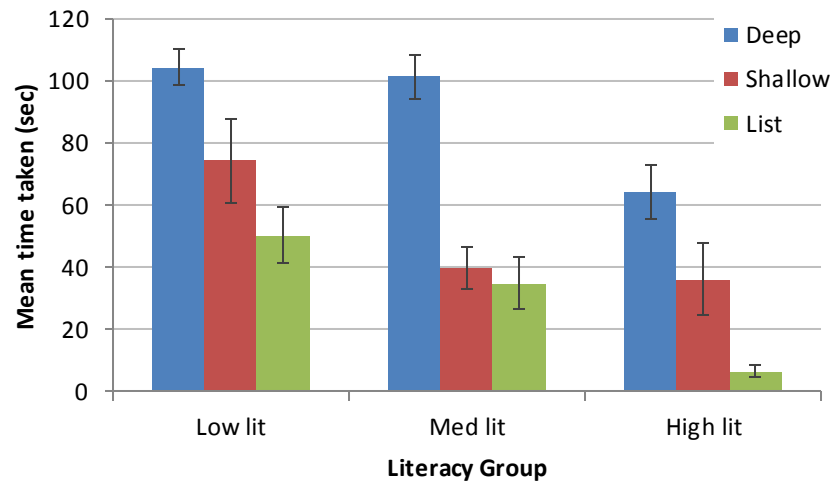


Fig. 20a: Mean time taken across all UIs by all literacy groups ($\pm$ SEM)

(Numerical values for the graph)

	Low literacy	Medium literacy	High literacy
Deep	104.22	101.31	64.02
Shallow	74.2	39.82	36.05
List	50.33	34.9	6.53

This finding is corroborated when we take mean % correct tasks as the dependent measure of performance. Refer Figure 20b. Participants with “high” literacy completed more correct tasks on the deep hierarchy, than both groups of participants with “low” literacy (average of 91 vs. 40), $t(12)=3.96$, $p<0.01$, as well as those with “medium” literacy (average of 91 vs. 34) $t(12)=4.76$, $p<0.01$. We observed that medium literacy participants actually completed similar % correct tasks (34) compared to low literacy participants (40) on the deep hierarchy, $t(12)=-0.37$, $p=0.72$. Medium literacy participants also completed similar % correct tasks (88) compared to low literacy participants (77) on the shallow hierarchy, $t(12)=1.139$, $p=0.28$. This could be because when it comes to hierarchies, literacy effects matter only after a certain level. Establishing where exactly that literacy level exists could not be established through our experiment.

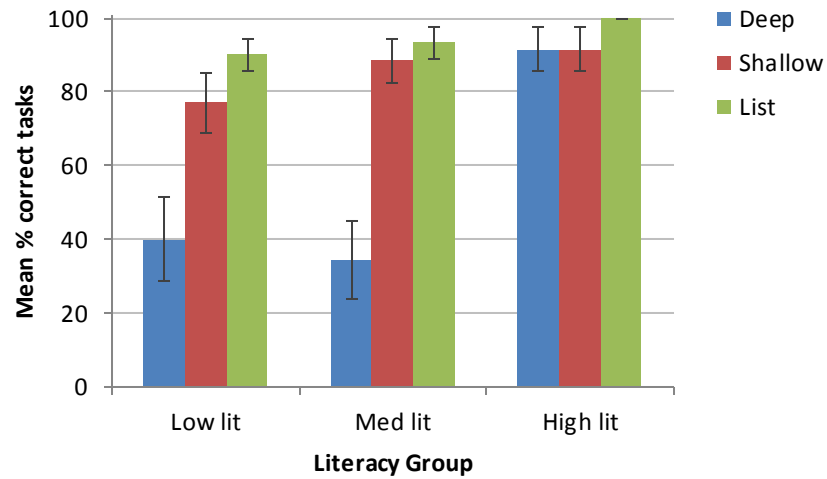


Fig. 20b: Mean % correct tasks across all UIs by all literacy groups ($\pm$ SEM)

(Numerical values for the graph)

	Low literacy	Medium literacy	High literacy
Deep	40	34.28	91.42
Shallow	77.14	88.57	91.42
List	90	93.33	100

As for “low” literacy participants, not surprisingly they performed better on the list than the deep hierarchy in terms of mean time taken (average of 50 seconds vs. 104 seconds) (Fig. 20a), $t(11) = 5.23$, $p < 0.01$. They also performed better on the list than on the shallow hierarchy (50 seconds vs. 74 seconds), though this is not significant, $t(11) = 1.43$, $p = 0.18$.

In terms of mean % correct tasks, again “low” literate participants performed better on the list than on the deep hierarchy. (90 on list and 40 on deep hierarchy) (Fig. 20b), $t(11) = 3.79$, $p < 0.01$. They performed almost about the same on the list and shallow hierarchy, (90 on list vs. 77 on shallow), $t(11) = 1.33$, $p = 0.21$.

Figure 21a illustrates the mean time taken for correct responses for each of the nine cells for the abstract reasoning groups. There are two main findings that are of particular interest. Confirming our third sub hypothesis, participants with “high” abstract reasoning required less time to navigate the deep hierarchy, than groups of participants with “low” abstract reasoning (average of 59 vs. 99 seconds), $t(12) = 3.25$, $p < 0.01$, as well as those with “medium” abstract reasoning (average of 59 vs. 99 seconds), $t(12) = 3.17$, $p < 0.01$. This finding is corroborated when we take mean % correct tasks as the dependent measure of performance. Refer Figure 21b. Participants with “high” abstract

reasoning completed more correct tasks on the deep hierarchy, than groups of participants with “low” abstract reasoning (average of 92 vs. 42), $t(12)=3.79$, $p<0.01$, as well as those with “medium” abstract reasoning (average of 92 vs. 45), $t(12)=3.09$, $p<0.01$.

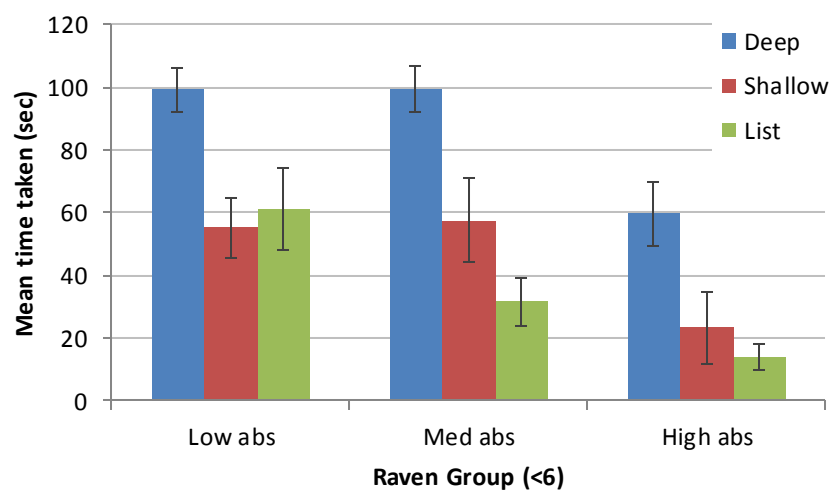


Fig. 21a: Mean time taken across all UIs by all abstract reasoning groups ($\pm$ SEM)

(Numerical values for the graph)

	Low abstraction	Medium abstraction	High abstraction
Deep	99.32	99.3	59.6
Shallow	55.17	57.57	23.35
List	61.4	31.53	13.76

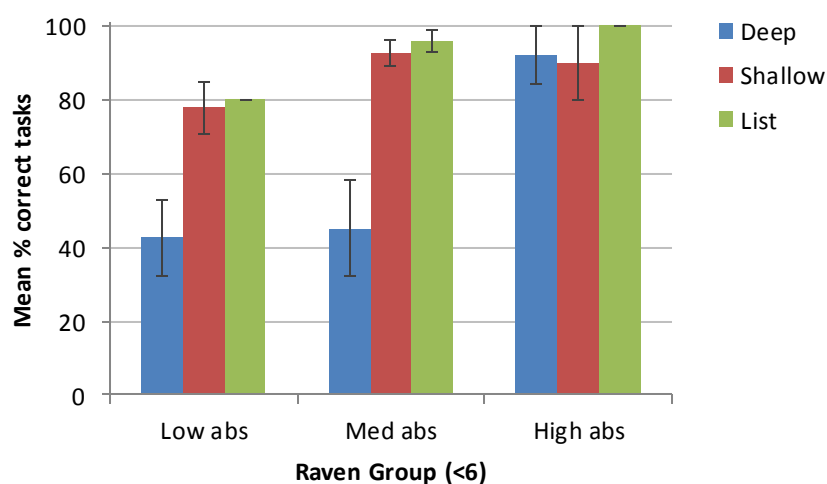


Fig. 21b. Mean % correct tasks across all UIs by all abstract reasoning groups ($\pm$ SEM)

(Numerical values for the graph)

	Low abstraction	Medium abstraction	High abstraction
Deep	42.5	45	92
Shallow	77.77	92.5	90
List	80	95.55	100

As for participants with “low” abstract reasoning, in terms of mean time taken, they performed almost the same between the list and shallow hierarchy (61 seconds on list vs. 55 on shallow), $t(10) = 0.344$, $p = 0.74$. Compared to the deep hierarchy they performed better on the list (61 seconds on list vs. 99 on deep), $t(9) = 2.75$, $p = 0.023$.

In terms of mean % correct tasks, participants with “low” abstract reasoning, performed about the same between the list and the shallow hierarchy (80 on list vs. 77 on shallow), $t(10) = 0.177$, $p = 0.86$. But compared to the deep hierarchy, they performed better on the list (80 on list vs. 42.5 on deep), although the difference is only borderline significant $t(9) = 2.15$, $p = 0.06$.

- Qualitative observations and discussion

We had a number of qualitative observations during the UI tests and follow-up qualitative interviews with the participants, which could inform future studies. First, some participants who could not complete tasks correctly or took more time on the hierarchical UIs did not seem to understand the concept of nesting, or that the top graphic in a hierarchy represented a group of pages. The video instructions shown before the use of the shallow and the deep hierarchies explained how (subordinate) items were “contained within” (super-ordinate) item categories, represented by a related graphic. It further explained how selecting that graphic would take the participant to the items contained within that category. But during the UI tasks, some participants randomly selected all unrelated graphics on any given page in the hierarchy. It also seemed like they did not understand how selecting items corresponded to movement within the hierarchy. E.g. to find a water pot, on the item categories page, a participant tapped graphics representing, “electronics”, “jewellery” and “games and sports”, instead of the one for “utensils”. This may also be because the participant became so anxious to complete the task that they tried all categories of items. However, our experimental study is unable to establish this conclusively. In the follow-up qualitative interviews, participants did not agree about being anxious during the UI tests, which might be because of participant response bias.

Second, some people did not remember how to navigate back to higher levels once they had gone down the incorrect path in the hierarchy. Further conversation revealed that they had forgotten the “back” button from the instructional video. We suspect this could be because of problems with short-term memory, attention during the video instructions, or issues with their ability to follow instructions.

Third, our follow-up conversations revealed that some participants did not understand that they had to apply what they had learnt in the instructional video to actual usage during the UI tests. One participant remarked, “But that was about animals and birds, and this is about clothes and TV sets.” This observation seems consistent with findings from our first experiment, which shows the effect of limited education on transferring relevant learning from an instructional video to actual practice.

As mentioned in the quantitative results section medium literacy participants completed less number of correct tasks (34) compared to low literacy participants (40) on the deep hierarchy. We said this could be because when deep hierarchy is concerned, literacy affects matter only after a certain level. Establishing where exactly that literacy level exists could not be established through our experiment. Though there seems to be a contradiction because we also saw that medium literacy participants completed more number of correct tasks (88) compared to low literacy participants (77) on the shallow hierarchy. Our study is unable to deduce why this is and it could be a limitation of our study design.

Again as mentioned earlier, participants with “low-literacy” performed better on the list UI than on the deep hierarchy (so did the all other groups of participants). However even on the list where all 40 items were visible all at once, many of them seemed overwhelmed at first sight as they had to scan through the items before spotting the ones asked for.

There may be a number of possible explanations for all these above observations, and we leave it to future work to explore them.

4.3.3 Summing up

In this study our hypothesis is proved **that skills required for navigation of hierarchical UIs are in fact correlated with levels of education, even when the UIs are Text-Free.** (*Like in the previous experiment, this was also based on using degree of textual literacy at the time of the experiment as the proxy for education.*) We showed that limited education is correlated with

abstract reasoning skills required in the navigation of top-down hierarchical UIs even when the UI has no text. In addition, we found that performance on both instruments, measuring textual literacy and abstract reasoning, are predictive of performance in hierarchical navigation. This provides statistically significant confirmation of previous anecdotal evidence from the Text-Free UI and DG studies. We observed that participants with basic education used the deep hierarchies in 38.4% less time than groups of participants with little or no education and 36.6% less time than those with some basic education. Participants with basic education also gave more than 2x accurate responses on the deep hierarchy than both groups of participants with little or no education and some basic education.

Surprising findings show similarity in performance between users with little or no education and those with some basic education, i.e. similar % correct tasks (34) compared to (40) on the deep hierarchy; also similar % correct tasks (88) compared to (77) on the shallow hierarchy. Based on these results our conjecture is that there is a threshold level of education beyond which the effective use of a hierarchy is impacted. Further research is required to establish where that threshold exists.

Furthermore across all groups of participants, with varying literacy and abstract reasoning levels, we observe that performance is better on the list UI design, which involved scanning through a list of items. Those with little or no education performed on the list UI design in half the time and completed more than 2x accurate responses, compared to the deep hierarchy. However, there still remain questions as to what is the most optimal list design, and to answer these questions we conducted the following study.

4.4 Hierarchical UI and List UI on mobile phones

The second experiment discussed above shows that participants with “low-literacy” performed better on the list UI than on the deep hierarchy (so did the all other groups of participants). However even on the list where all 40 items were visible all at once, many of them seemed overwhelmed at first sight as they had to scan through the items before spotting the ones asked for. All 40 items were seen at once on the PC screen in this list design. But that is frequently not an option for any real design on smaller devices where real estate is constrained. Among smaller devices, mobile phone prices are rapidly dropping and people across income groups are getting access to them. Given this heavy proliferation of mobile phones, it is pertinent for us to study navigation on them

among low-literate users. What happens when it is not possible for items to be visible all at once on a list UI on a mobile phone with constrained real estate? One of the principle benefits of hierarchies (and IAs in general) is that space needed for navigation can be reduced by nesting, however the second experiment showed that people with low-literacy and low-abstract reasoning performed poorly on deep hierarchies. What then if listed items are across multiple pages on a phone? How would it be compared to a deep hierarchy where all of the items at a given level (maximum 5, refer to deep UI hierarchy design of the second experiment) are all visible at once? Are the results from the second experiment reversed now, given that the screen size is smaller, and finding a list item requires a user to traverse through multiple pages of a list? Are the results basically the same—e.g., the real issue is cognitive organization and understanding ontologies and representations? Or perhaps it is found that the difference in terms of time taken and mean % correct tasks gets minimized between the list and the deep hierarchy on the phone? Or is it that the multiple-page list design works better given it is no longer overwhelming to see all of the items all at once like in a single-page list?

To answer the above questions, as a follow-up to the second experiment we ask the following research question: **What is the trade-off for low-literate participants (or those with little or no education) between a multiple-page list UI design on a phone where all items are not visible all at once, and a deep hierarchy where all items at any particular level are visible all at once?** (*This again is based on using degree of textual literacy as the proxy for education, like in the previous two experiments*). We conducted a controlled follow-up experiment (11 months after the second experiment) on a phone interface that compared 10 non-literate participants on their performance on a multiple-page list UI with another 10 non-literate participants on their performance on a deep hierarchy.

4.4.1 Study Methodology:

- UI prototypes

Consistent with the second experiment, the domain for design of the UIs was household items and each of these items were represented by photographs. The test again was for finding items. Each of these UI prototypes were displayed on a Samsung GT-I8350 running Windows Phone 7.5. The two prototypes were:

- **A list UI of 40 items, organized in a 3X2 matrix over a total of 7 pages;** there were 6 items per page up to the 6th page and then the remaining 4 items (in a 2X2 matrix) on the 7th page. We took the layout of the list UI from the second experiment (refer Figure 13) and divided up the items into groups of 6 to be placed on consecutive individual pages on the phone UI (the 7th page had the remaining 4 items). This resulted in loose categories of items per page sometimes flowing into subsequent pages. There were forward and backward arrows that had to be tapped to traverse between the pages of the list UI on the phone. To select any item, the test participant had to point to the item with his/her finger. See Figure 22a and 22b.



Fig. 22a: 1st page of the list UI on phone with a forward arrow

Fig. 22b: 5th page of the list UI on phone with a forward and a backward arrow

- **A deep hierarchy UI of 40 items (4 levels deep and average branching factor of 3).**

This design was the same as the second experiment except that it was presented on a phone. To recap, the items here were organized in a top-down navigation tree based on four levels of organization: first level is how the item is used (e.g. things you wear, things you use), second level is item category (e.g. Clothes, electronics, jewellery, etc.), third level is item sub-category (Men's clothes, living room electronics, hands jewellery, etc.) and fourth level is type of item (Shirt, TV set, bangles, etc.). Refer Figure 23. On the UI, each node of the organization was represented by a photograph that best depicted that node.

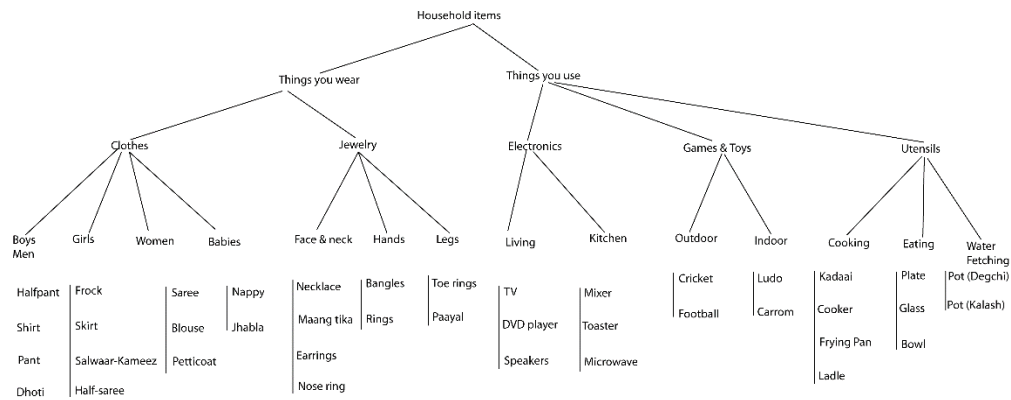


Fig. 23: Deep UI architecture on phone (same as Fig. 13 Deep UI Architecture)

To select any given item, test participants had to make four choices down the navigation tree in the deep hierarchy to arrive at a given item. Tapping on the image of on a certain graphic would take the user to the next level of the hierarchy. There was the provision to go back to the previous page in the hierarchy by clicking on a “back” button at the bottom on any given page (Figure 24). Compared to the second experiment on the Tablet, for the design on the phone we enlarged the size of arrow to allow for more tap area size on the touch screen of the phone. The area of the arrow was designed based on informal usability tests conducted with 5 users from our participant community.



Fig. 24. Screenshot of a page from the deep hierarchy UI

Process of administering the UI test

Every participant was randomly allotted one of the prototypes (list / deep hierarchy). Like in the previous experiment, participants were asked to carry out five tasks: each task required them to find a household item on the UI that was allotted: a set of bangles, a water pot, a football, a pair of shorts and a mixer-grinder. To keep things consistent with the second experiment, there was a time

limit of 2 minutes for every task. Consecutive tasks were announced only after the previous task was over. There was a standard script of verbal instructions provided at the beginning of the test by the experimenter. Please refer to Appendix XI for details.

Before using the UI prototype, for both the phone list UI and the phone deep hierarchy, participants watched an instructional video on how to use the UIs on the touch screen phone interface (of 1 min 58 secs for the list UI video and 2 min 8 sec for the deep hierarchy UI video). Refer Figure 25 for screenshots and Appendix XII for the scripts. Unlike in the second experiment the time duration of both videos were different, since the deep hierarchy video required more time to explain the concept of nesting than the list video (In study 2, the single page PC list did not have an instructional video).

Both the instructional videos also had details about how to tap on the phone screen to go to the other pages by clicking on the arrows, or in the case of the deep hierarchy, on a given graphic. Participants could watch the video as many times as they wanted, up to a maximum of three times. The time taken to watch the video was not accounted for during performance evaluation on either of the UIs. For consistency with the previous experiment, the domain for the instructional video was animals-birds kingdom instead of household item, so there was no learning effect on the actual tests. There was no assistance provided by the experimenter during use of the UIs.



Introducing the deep phone UI



Explaining nesting of deep phone UI



Introducing the list phone UI



Explaining listing on list phone UI

Fig. 25: Screenshots of the instructional video for deep phone UI (top) and list phone UI (bottom)

- **Testing for education level and abstract reasoning**

This follow-up experiment was solely with non-literate participants. So unlike the previous experiments, we did not need to group participants based on literacy levels. Moreover none of these participants had any formal education and were unable to read and write text in the local language, so no literacy tests were conducted.

Our second experiment had also shown a correlation between literacy levels and Raven's test scores for abstract reasoning, so we did not repeat the Raven's test in this study.

- **Participants**

Like the first and second experiments, here too we recruited participants because of their convenient accessibility and proximity to our partner organizations (described in the section Participant Communities in section 4.1). All 20 test participants for the experiments were drawn from these communities. Fulfilling our primary criteria, all of these participants had no formal education and did not have any previous experience using computers. Furthermore, none of them had any previous experience using touch screen phones.

- **Experimental Procedure**

For consistency, like in the previous experiment, the same researcher acted as experimenter for all participants and followed a script. Please see Appendix XI. Participants came in one by one. The researcher first gathered information about the participant such as their age, and asked if they had any formal education and technology experience, particularly with touch screen phones. Then, each participant took a UI prototype test. We conducted a between-subjects experiment design. Unlike in the previous experiment, there were 2 kinds of UI prototypes-- list and deep hierarchy. There were a total of 20 participants, 10 of who were randomly assigned to the list and the other 10 to the deep hierarchy. Attempts were made to balance both the groups across age and gender. The experimental design is illustrated in Table 7, together with mean and median ages and gender break-up.

Table 7. Between-subjects experimental design with 20 nos. of participants (m=male, f=female)

List	Deep
10 nos. (5 m, 5 f); mean age: 38.8 yrs Median age: 36.5 yrs	10 nos. (5 m, 5 f); mean age: 38.2 yrs Median age: 38.5 yrs

Dependent variables

The dependent variables that we measured are as follows:

- UI test: Number of correct tasks (maximum 5), Total time taken for correct tasks, Total time taken (maximum 10 minutes for incorrect and correct tasks combined)

- Documentation

Like in the previous experiment, to make the process of experimentation less intrusive, we did not video record the user tests. We collected notes in situ on paper and timed the UI prototype use. Select photographs of the test participants and testing environment were also taken. There was 1 experimenter and 1 additional scribe for note-taking.

- 4.4.2 Results

In this section we measured time taken to complete tasks correctly and correctness of the tasks. We present the analysis below. Raw data is in Appendix XIV.

- Quantitative

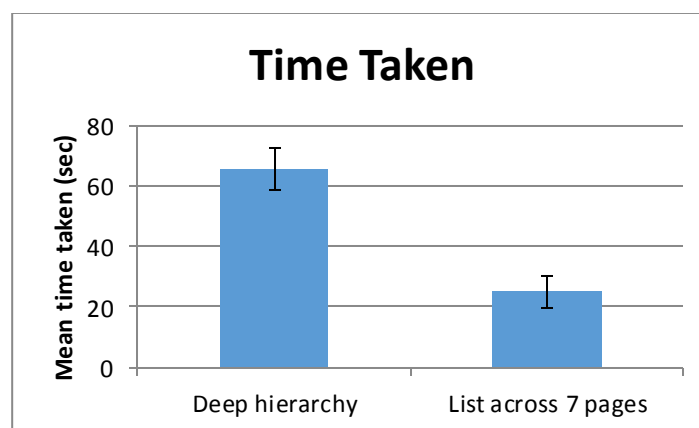


Fig. 26: Mean time taken across UIs (±SEM)

Figure 26 illustrates the mean time taken for correct responses for each of the UIs. Results show that the multiple-page phone list UI required significantly less time to navigate than the deep hierarchy phone UI (average of 25 vs. 65.5 seconds) (i.e. 61.8% less time) $t(18)=4.6$, $p<0.001$.

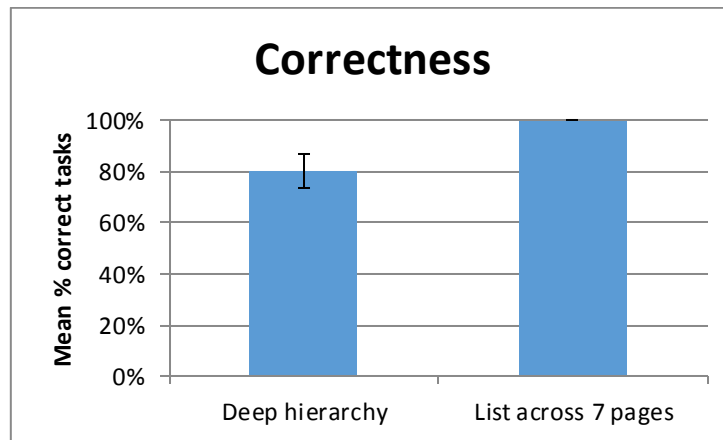


Fig. 27: Mean % correct tasks across UIs ($\pm$ SEM)

This finding is corroborated when we take mean % correct tasks as the dependent measure of performance. Refer Figure 27. Participants completed more correct tasks on the multiple-page phone list UI than on the deep hierarchy phone UI (average of 100 vs. 80), (i.e. 1.25x correct tasks on the phone list), $t(18)=3$, $p=0.0077$.

- Qualitative observations and discussion

We had a number of qualitative observations during the phone UI experiment tests and informal interviews with the participants, some of which are consistent with the observations from the PC-based second experiment with respect to use of the deep hierarchy: participants had difficulty in understanding the concept of nesting or that a node in a hierarchy represented a group of pages; and also understanding how selecting items corresponded to movement within the hierarchy. We suspect hierarchies (whether on the phone or on the PC) are difficult because the user has to remember they are on a hierarchy and hold it from the root in their thinking. Whereas list navigation really does not require a user to remember much, nor does it presumably require abstract thinking by our definition – it is just moving back and forth and knowing where he/she is along a single line. We will return to a *quantitative comparison* of performances between the phone hierarchy and PC hierarchy shortly.

Apart from the above we had other interesting qualitative observations with respect to use of the multiple-page list UI on the phone. We observed that even though the items were spread out across 7 pages and not all of the items were visible at once (unlike in the PC-based list), participants did not hesitate to move about quickly through the pages. We note here that the multipage phone list

would not have required abstraction in thinking, as per our definition, like the hierarchies did. Once participants realized that the task item was not available on the first screen, and remembered (from the instructional video) that they had to press the “forward” arrow to reveal an item, they seemed to promptly go about using this tap-on-arrow feature. Even though none of our participants had any previous experience using a touch screen phone, they seemed relatively more comfortable using this device than the group of participants who had used a single-page list UI on the PC. We suspect this could be because of general familiarity with the form factor of a phone, even though the interaction was through the touch screen, which none of our participants had used earlier. It could also be that factors of self-efficacy and/or confidence intervened in interaction with the PC versus the phone. Our experiment is unable to establish the cause of the difference in performance conclusively, but we will return to a *quantitative comparison* of performances between the phone list and PC list shortly.

Also, the “back” button seemed to have a better recall on the phone list UI, as compared to on the deep hierarchy on the phone. When participants needed to go back to the previous page on the phone list UI, they pressed the “back” button without much hesitation. We suspect the recall was helped by the placement of this button right beside the “forward” button (refer Figure 22b) that they already had to use in any given task (except in the final task where the item was on the first screen and neither the forward or back button had to be used). The difference between the two arrows was indicated by their directionality.

Given the seemingly interesting qualitative differences between the list UI on the phone and that on the PC, in the following section we offer analysis of results of the performance of the list UIs on the phone vs. on the PC. We follow it up with an analysis of the performance of the hierarchy UIs on the phone vs. on the PC, again because of the seemingly interesting differences in performance.

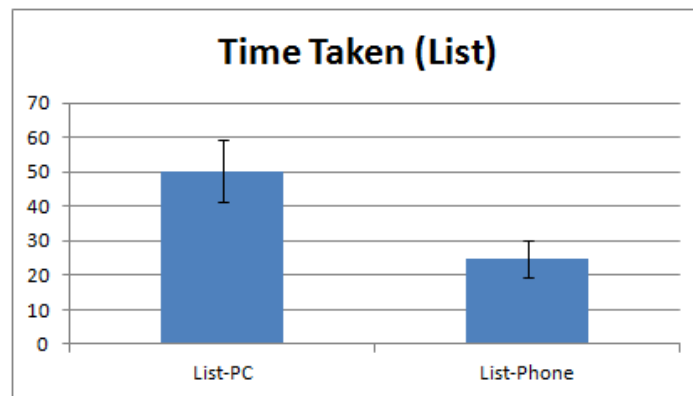
- 4.4.3 Comparison of the list UIs on the phone and PC

The follow-up phone study was conducted 11 months after second experiment on the PC. In other words there were differences not just in form factor of the devices, but also time period when participant groups for the two studies were sampled. In addition, the participants who tested on the PC list UI took a literacy test, whereas the participants who tested on the mobile list UI did not.

Given all of this, we caution our readers against broadly generalizing the results from this comparison, as any differences in results could have been not just due to form factor, but also difference in participant sampling and using different methodologies.

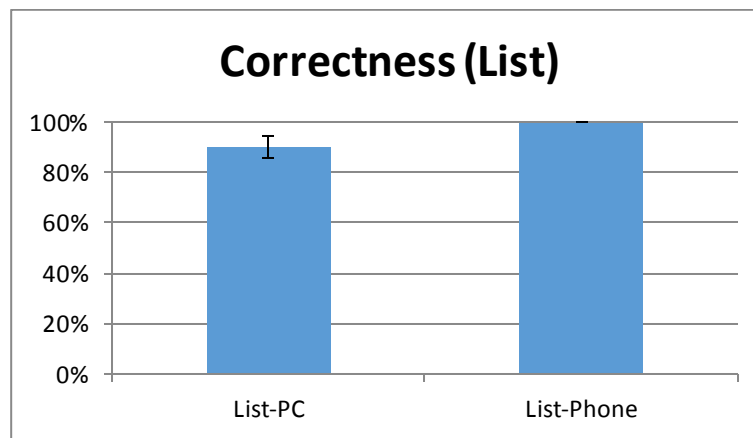
Our hypothesis for this comparison was that the test participants on the multiple-page phone list would do significantly worse, than participants on the single-page PC list (from the second experiment). This was because finding task items on the phone list required participants to traverse through multiple pages (total 7 nos.) while on the PC list all items were available all at once on a single screen.

Much to our surprise our hypothesis was disproved; Figure 28 illustrates the mean time taken for correct responses for the single-page list on the PC and the multiple-page list on the phone. **Results show that disproving our hypothesis , the multiple-page phone list in fact did better by requiring less time to navigate than the single-page PC list** (average of 25 vs. 50.33 seconds), (i.e. 50% less time), $t(14)=2.60$, $p=0.021$.



- Fig. 28: Mean time taken across list UIs, on the PC vs. phone ($\pm$ SEM)

This finding is corroborated when we take mean % correct tasks as the dependent measure of performance. Refer Figure 29. **Participants completed more correct tasks on the multiple-page phone list than on the single-page PC list** (average of 100 vs. 90), (i.e. 1.1x correct responses on the phone list), $t(14)=2.96$, $p=0.01$.



- Fig. 29: Mean % correct tasks across list UIs, on the PC vs. phone ($\pm$ SEM)

We suspect that the multiple-page phone list design works better given it is no longer overwhelming to see all of the items all at once like on a single-page on the PC list. Furthermore it could be that the form factor of the phone device is also more familiar than the PC. Or that factors of self-efficacy and/or confidence intervened in interaction with the PC versus the phone. Our experiment is unable to establish the cause of the difference in performance. Finally, it could also be that the participants who used the PC list were fatigued after the literacy and Raven's tests. Our tests are unable to identify the cause(s) conclusively.

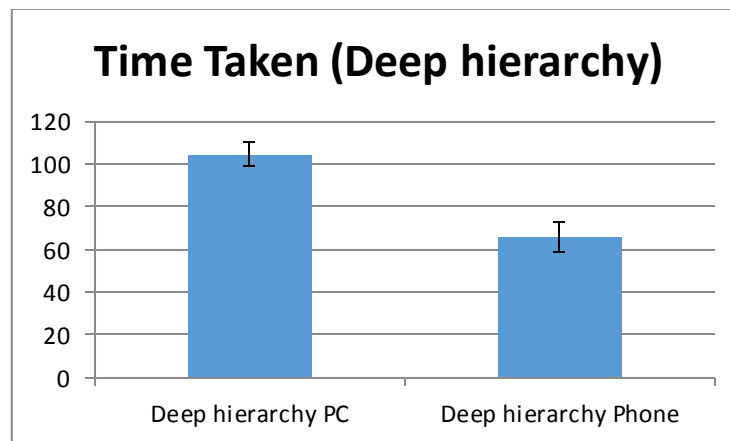
- 4.4.4 Comparison of the deep hierarchy UIs on the phone and PC

As mentioned in the previous section the follow-up phone study was conducted 11 months after second experiment on the PC. In other words there were differences not just in form factor of the devices, but also time period when participant groups for the two studies were sampled. In addition, the participants who tested on the PC deep hierarchy UI took a literacy test, whereas the participants who tested on the mobile phone deep hierarchy UI did not. Given all of this, we caution our readers against broadly generalizing the results from this comparison, as any differences in results could have been not just due to form factor, but also difference in participant sampling and using different methodologies.

Our hypothesis for this comparison was that the test participants on the phone deep hierarchy would do almost equally as the participants on the PC deep hierarchy (from the

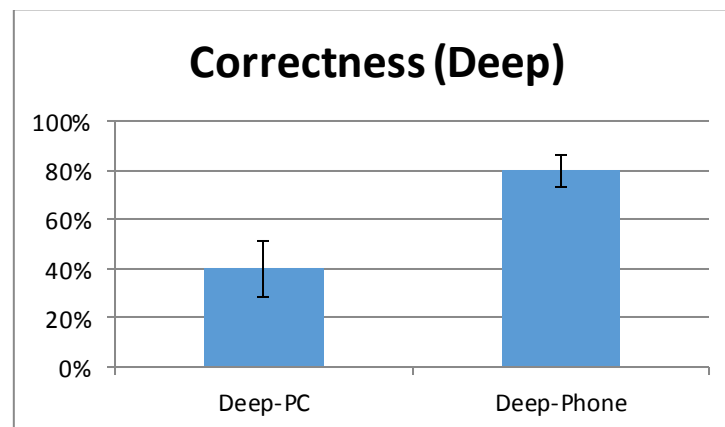
second experiment). This was because the design of the hierarchies was constant between the phone and PC, although the devices they were presented on were different.

Again to our surprise, our hypothesis was disproved; Figure 30 illustrates the mean time taken for correct responses on the deep hierarchy on the PC and the deep hierarchy on the phone. **Results show that disproving our hypothesis deep hierarchy on the phone in fact did better by requiring less time to navigate than the deep hierarchy on the PC** (average of 65.46 vs. 104.22 seconds), (i.e. 37% less time for the deep hierarchy on phone), $t(15)=5.29$, $p<0.001$.



- Fig. 30: Mean time taken across deep hierarchy UIs, on the PC vs. phone ($\pm$ SEM)

This finding is corroborated when we take mean % correct tasks as the dependent measure of performance. Refer Figure 31. **Participants completed more correct tasks deep hierarchy on the phone than on the deep hierarchy on the PC** (average of 80 vs. 40), (i.e. 2x correct responses on the deep hierarchy on phone), $t(15)=3.21$, $p=0.0059$.



- Fig. 31: Mean % correct tasks across deep hierarchies, on the PC vs. phone ($\pm$ SEM)

- We suspect that the deep hierarchy on the phone works better, even though the design of the hierarchies are the same, because of the familiarity of the form factor of the phone device. Or that factors of self-efficacy and/or confidence intervened in interaction with the PC versus the phone. It is also possible that the participants who used the deep hierarchy on the PC could be fatigued after the literacy and Raven's tests. Our tests are unable to identify the cause(s) conclusively.

- 4.4.5 Summing up

Our second experiment on the PC had shown that in the context of tasks for finding familiar items, a list UI design that displays all items at once on a PC screen worked better than a UI where items are categorized under a top-down navigation tree of a deep hierarchy. But displaying all search items at once on a screen is frequently not an option for devices such as mobile phones where screen space is limited.

In the follow-up to the second experiment we investigated the trade-off of paging through multiple pages of a list UI on a touch-screen phone, compared to a phone hierarchy where all of the items at a given level are all visible at once. The items on the phone list UI spread across 7 pages. Our results showed that both in terms of time taken and percent correct, non-literate users with no formal education using the multi-page phone list UI performed better than both the phone hierarchy and a single-page PC list. Compared to the phone hierarchy, the phone list required 61.8% less time and had 1.25x accurate responses. Disapproving our hypothesis and much to our surprise, compared to the single-page PC list from the second experiment, the multipage phone list required half the time and had 1.1x accurate responses. This is even when the phone list design required participants to browse through multiple pages of the phone.

Also, disapproving our hypothesis, compared the PC deep hierarchy from the second experiment, the phone hierarchy required 37% less time and had 2x correct responses. Based on this, it is possible that if the form factor of the device is familiar, (or when users have more self-efficacy and/or confidence with a device) then a deep hierarchy (not more than 4 levels deep, and average branching factor of 3) may be navigable even by non-literate users without formal education.

Chapter 5: Overall summing up and design recommendations

In this thesis we presented three experimental studies with people from low-income communities in India, which explored correlations between levels of education and cognitive skills for, a) transfer of learning in video-based training for technological appliances, specifically vacuum cleaners, and b) hierarchical navigation of PC and mobile phone UIs, specifically for finding 40 familiar household items. Based on results from these experiments, we make recommendations for presentation of training videos for technological appliances and information architecture design for PC and mobile phone UIs for search tasks of familiar items here. Please note that this is not an exhaustive list.

Through our first experiment we proved our hypothesis that skills required for transfer of learning in video-based training are in fact correlated with levels of education. We conducted this experiment in the context of vacuum cleaner use. We showed that users with some basic education (as measured by our literacy test) required less than half as much assistance as users with little or no education on all transfer tasks in a video-based skills training exercise for operating vacuum cleaner appliances. We also showed that users with little or no education did not benefit from generalized examples in the training video as a way to learn abstract concepts, as much as participants with some basic education did. Presenting instructions, within the same video, for a second vacuum cleaner with part similarities and part variations vis-à-vis the first did not help users with little or no education, to transfer learning to a third vacuum cleaner not featured in the video.

Based on this our recommendation for presenting video instructions to users with little or no education is to, as much as possible, not change the form factor of product(s) demoed in the video with respect to the product that will be used. If there is change in form factor of what is demoed, it is important to understand implications for usage—that transferring learning to use of a different form factor might be challenging for end users, and related training videos would be required. Particularly for video instructions for people with little or no education, they should demonstrate examples that are as close as possible to actual instances of the task. As much as possible the

instructions should be for the same set of design features, buttons layout and other specifications as the product to be used. Such video production could be a resource intensive process, given all products with even minimum feature variation will require a distinct training video. But if a product's primary target is customers with little or no education, having distinct video instruction manuals would serve to be an essential presentation strategy for effective use.

In our first experiment, for people with some basic education, seeing a generalized example—one plus one example in the video-- led to 30% less assistance required to transfer learning to a device not seen in the video. Based on this while designing video demonstrations for groups with some minimal basic education, our recommendation would be to present instructions in a way that highlights similarities between product(s) demoed and the product that is to be used (if they are different from each other). It might be possible to include variations of an actual task or a feature, instantiated through another example of the product within the same video. E.g. 1) finding attachments of a vacuum cleaner under the lid of the canister, to finding attachments of the vacuum cleaner in the crevices on either side of the canister near its base, 2) locating the on/off switch of the vacuum cleaner on the lid (of a bagged canister model), to locating the on/off switch at the end of handle (of a bagless canister model).

Overall, based on our first experiment, we observed that a general ability for abstraction seemed to be an important cognitive skill for effective transfer of learning from watching video instructions to actual practice. This ability for abstraction seemed to be what helped participants identify common attributes and connections between the training video and the real-world tasks in the vacuum cleaner use, and to adapt to different attributes. We thus realized that going forward in our experiments, wherever there would be the need to identify common attributes and connections, measuring abstract reasoning skills would also be important, in addition to measuring literacy levels. We measured abstract reasoning using the Raven's Progressive Matrices, where participants had to identify missing elements that completed specific patterns. To fill in the missing elements, the matrices required seeing connections between the other given elements of the patterns.

Following our first experiment we conducted our second experiment where we proved our hypothesis that skills required for navigation of hierarchical UIs, are in fact correlated with

levels of education, even when the UIs are Text-Free. We conducted this experiment in the context of finding 40 familiar household items. We showed that limited education is correlated with abstract reasoning skills (as measured by Raven's Progressive Matrices), required in the navigation of top-down hierarchical UIs even when the UI has no text and instead, all photographs. The tasks were for finding familiar household objects –clothes, jewellery, electronics, utensils, games and sports items—the total not exceeding 40 items and all represented by photographs. We observed that participants with little or no education needed 38.4% more time to use deep hierarchies on the PC (not exceeding 4 levels, and average branching factor of 3) than groups of participants with some basic education. They also gave less than 0.5x accurate responses on the deep hierarchy on the PC than the participants with basic education. Based on this one might consider avoiding hierarchies when designing UIs for users with little or no education. However, **in our follow-up third study, much to our surprise, we observed that compared to the deep hierarchy on the PC, the touch-screen phone hierarchy with the exact same hierarchical organization required 37% less time to navigate and had 2x correct responses.** Based on this, it is possible that if the form factor of the device is familiar to end users, or when users have better self-efficacy and/or confidence with a device--such as a mobile phone-- then a deep hierarchy (not more than 4 levels deep) for finding 40 familiar household items may be navigable even by non-literate users without formal education. ***But to the extent possible, we recommend that when designing for users with little or no education, designers keep navigation linear with groups of items spread (in a 3x2 matrix) across pages of the mobile, in a predefined order, even when there are as many as 40 items.*** This is since we observed in our third experiment itself that compared to the phone hierarchy, users with little or no formal education used the multipage list design on the phone in 61.8% less time and had 1.25x accurate responses. We suggest providing list of items across multiple pages (up to 7 in nos. if the domain allows on a phone), with items loosely grouped together by categories on each page. In the case of the familiar household items the loose categories across pages were clothes, jewellery, electronics, utensils, and games and sports items.

But why a multipage list design on the phone if all 40 items can be accommodated on a single page list on a larger device such as a PC? We recommend the above because **in our third experiment, much to our surprise we also observed that users using multi-page phone list (7 pages) performed significantly better than the single page PC list where the exact same 40 items**

were visible all at once. The 7 page phone list required half the time and had 1.1x accurate responses as compared to the single page PC list.

Chapter 6: Contributions and Future Work

In the thesis we started with anecdotal knowledge from the Text-Free UI research and our DG studies, which indicated that people who are low-literate might experience challenges when transferring learning from video-based skills to actual practice and while navigating UI hierarchies. We followed this with a study of the theoretical underpinnings of transfer of learning, hierarchical UI navigation and research in cognitive science related to literacy, both in the developed and developing worlds. Relevant work had showed that low-literate users and cultures learnt better in situ, through experiences embedded in concrete, practical situations, than learning from neutral stand-alone systems with instructions (Ong, 2002; Sherwani et.al. 2009). However these previous studies only provided anecdotal evidence for the observations. Three other relevant previous studies questioned the suitability of menu-based navigation for low-literate and novice users in the developing world context (Jones & Marsden, 2005; Jones et.al., 2000; Katre, 2006). These works discussed challenges in navigation and made design recommendations for low-literate users. But this work included qualitative studies, exercises, case studies and worked examples. The above left the gap for research that would provide experimental evidence for the following questions:

- Is transfer of learning in video-based skills training difficult for low-literate users? If yes, in what way?
- Is hierarchical UI navigation difficult for low-literate users? If yes, in what way?

- 6.1 Contributions

The main contribution of our thesis is concrete proof of hypotheses from three controlled experimental studies that skills required for transfer of learning of video-based training, at least for vacuum cleaner use, and for navigation of hierarchical UIs, at least for the tasks of finding 40 familiar household items, are correlated with levels of education (as measured by our literacy assessment tools). Our work reconfirms implications of previous work (Ong 2002; Sherwani et.al. 2009) as we show that users with little or no education experienced challenges in transferring learning from instructional videos, a kind of stand-alone system with instructions. Our work offers support to other previous work (Jones & Marsden, 2005; Jones et.al., 2000; Katre, 2006), in that hierarchical UIs are challenging to use for users with little or no education. We specifically show

that to navigate through hierarchies not exceeding 4 levels and average branching factor of 3 on the PC, users with little or no education took more than 2x the amount of time compared to a single-page list of the same items (104 seconds vs. 50 seconds). They also gave less than 0.5x correct responses on the PC hierarchy compared to the single page list of the same items (40 vs. 90). Our work adds further new knowledge by showing that if the form factor is familiar, or when users have better self-efficacy and/or confidence with a device (e.g. a mobile phone), then the very same hierarchical design can become usable by users with little or no education. We show that users with little or no education gave 0.8 correct answers on the mobile phone hierarchy compared to the mobile phone list of items spread over 7 pages (80 vs. 100). This is all in the context of finding 40 familiar household items and whether it generalizes to other contexts needs further research.

Our three experimental studies were conducted with study participants drawn from 5 urban low-income, low-literate slum communities in Bangalore, India. In addition to concrete evidence that skills required for transfer of learning of video-based training, at least for vacuum cleaner use, and for navigation of hierarchical UIs, at least for the tasks of finding 40 familiar household items, are correlated with levels of education, we had some surprising findings that complemented or did not complement our experimental hypotheses and we list selected ones here below.

Our first surprising finding is the similarity in performance between users with little or no education (“low-literacy”) and those with some basic education (“medium literacy”) in our second experiment. Medium literacy participants completed similar number of correct tasks (34) compared to low literacy participants (40) on the deep hierarchy. They also completed similar number of correct tasks (88) compared to low literacy participants (77) on the shallow hierarchy. Based on these results our conjecture is that there is a threshold level of education beyond which the effective use of a hierarchy is impacted. We had similar observations in the groups divided according to their performance on the tests for abstract reasoning, as measured by the Raven’s Progressive Matrices. We observed that the “medium abstract reasoning” group performed about the same number of correct tasks (45) as compared to the “low abstract reasoning group” (42), on the deep hierarchy. In fact our second experiment showed that there was a correlation between literacy scores and abstract reasoning test scores for our participants.

Our second surprising finding is that single page list where all 40 search items were visible all at once on the PC screen did worse compared to the multipage list where 40 search items were listed

across 7 pages of the mobile phone. The items on the multipage phone list were organized in a 3X2 matrix over a total of 7 pages; there were 6 items per page up to the 6th page and then the remaining 4 items (in a 2X2 matrix) on the 7th page. Results showed that our 7 page phone list required half the time to navigate and had 1.1x accurate responses as compared to the single page PC list.

Our third surprising finding is that familiar form factor, or self-efficacy and confidence with a device, is quite critical in user experience among people with little or no education. In our first experiment studying the transfer of learning in video-based skills training we observed that users with little or no education did not benefit from generalized examples (two in number) in a training video for using an appliance model not shown in video. In fact familiarity, and/or self-efficacy and confidence with form factor also seems to compensate for education levels as we observed in our third experiment. Much to our surprise, compared to the deep hierarchy on the PC, the phone hierarchy with the exact same design required 37% less time to navigate and had 2x correct responses. Based on this, it does seem like the familiarity and/or self-efficacy and confidence with the form factor of the phone allowed users with little or no education to even navigate a deep hierarchy of 4 levels. We caution our readers against broadly generalizing the results from this latter comparison however, as any differences in results could have been not just due to form factor, but also difference in participant sampling over different points in time.

Apart from the main contribution and surprising findings listed above, a minor contribution in this thesis is demonstrating through our experimental studies that it is possible to measure levels of education and abstract reasoning among limited education users. For measuring abstract reasoning we used an existing tool, the Raven's Progressive Matrices (Raven, 1936; Raven 1981). It was a literacy-independent test and the most cited and validated in psychology literature for measuring abstract reasoning.

For measuring education level, we presented a literacy testing tool that allowed for a more nuanced categorization of test participants in our second study. It was devised by borrowing content from standard local language government school textbooks (Government of Karnataka Board of Education, 2008). Every level had two sections: reading and writing, with a total numerical scoring of 50. The internal validity of the instrument was not tested. While we present the above two tools, for measuring education of limited education users, we consider these only minor and secondary contributions of this dissertation.

- 6.2 Future Work

While our first experiment to test transfer of learning in video-based skills training was conducted in the context of vacuum cleaners our conjecture is that many of the observations will apply to other technological appliances e.g. Mixer-grinders, washing machines, etc. where there are different degrees of variations in features within a product category. As part of future work it would be good to verify if the observations for transfer of learning in video-based skills training do in fact apply to these other technological appliances. This could be done by replicating our first experiment among low-literate users in the context of these other devices. Future work is also required to establish which features of a technology appliance might generalize better than others within an instructional video, to be transferred for actual use. For this, a study comparing the transferability of different features of the technology to actual usage will need to be designed.

In addition to the above as part of future work it would be interesting to see how improved design of video can affect transferability of learning. In our first experiment we presented two kinds of videos: a) specific, with instructions for the same vacuum cleaner repeated twice and b) diversified, with instructions for two different vacuum cleaners. In future work it would be good to experiment with other formats of video design and presentation and observe how that affects transfer of learning, or if our hypotheses can be disproved.

Our second and third experiments to test ability for navigation of UI hierarchies were conducted in the context of finding 40 nos. of familiar household items. Our conjecture is that observations from these two studies would apply to domains, which contain a similar number of items e.g. agricultural crops grown in a particular geography. Whether or not this is true can be verified by replicating our experiments for that set of items as future work. Do our recommendations for multipage design of items loosely grouped together per page in a predefined order on a mobile phone still hold? Establishing what the optimal number of pages for effective multipage list design is needs further research. It would also be interesting to study what happens to user experience when the number of items increases beyond 40 and/or the number of pages increases beyond 7.

Our second experiment showed similarity in performance of tasks on the deep and the shallow hierarchies, between users with little or no education (“low-literacy”) and those with

some basic education (“medium literacy”). Based on these results our conjecture is that there is a threshold level of education beyond which the effective use of a UI hierarchy is impacted. In future work it would be interesting to establish where this threshold exists.

We also showed in our second experiment that there is a correlation between literacy and abstract reasoning as measured by tests of Raven’s Progressive Matrices. The Raven’s Matrices as we have described earlier are literacy-independent tests. And going forward it would be interesting to see if Raven’s (abstract reasoning skills) can be used as a proxy to test for participants’ literacy levels, instead of a literacy test. It would also be interesting to study the similarities and the differences between these two skills. When is abstract reasoning learnt as a skill? Is it learned through formal education or through other life skills?

Moving on, in our first and second experiments we had used two literacy assessment tools, one that allowed for a binary categorization of test participants, and the other that allowed for a more nuanced categorization of them. In future work, it would be good to statistically validate the reliability of the tools themselves.

Finally taking a departure from our three experimental studies, as future work it would be interesting to study how users with little or no education solve existing everyday problems using ICTs e.g. managing phone contacts on a mobile phone. A different methodological orientation would be required for this; a qualitative study looking at strategies used as workarounds by users with little or no education could make for an interesting research direction.

Appendix I

Digital Green (<http://www.digitalgreen.org/>) training module:

Pico projector:

Here's a step-by-step break down of what it took for participants to learn to use the pico projector effectively:

- 1) Explanation of concept (object at hand):
 - a) Explanation of the main function of the projector through quoting of a relevant example – “It projects a screen on a wall like a TV screen”
- 2) Demonstration of the object:
 - a) Demo of the main function of the pico projector without exposing the UI complexities (Projection displayed on the wall shown)
 - b) Step-by-step demo of how the pico projector works (Fixing the stand, switching on projector, using projector) with details explained through relevant examples e.g. TV remote (playing movie, pausing, skip movie, stop, stand removal)
 - c) Repeat of the step-by-step demo
- 3) Practice
 - a) Allowing the participant to touch and feel the object
 - b) A solo do-it-yourself exercise with assistance from the trainer
 - c) A solo do-it-yourself exercise without assistance

There was of course some variation in the learning abilities of the participants—some people needed more assistance than others, some people needed more than 2 demo sessions, etc. But almost all of them learned to use the projector independently in 1-2 days. For internalizing, it required use of the projector from time to time (once every week) for 1 month for assistance-free usage every next time.

Video camera:

The video camera had a more complex UI than the pico-projector and it thus required a more elaborate concept explanation, demo and practice session than the pico-projector. Here's a step-by-step break-down:

- 1) Explanation of various concepts, through photographs, slides and real-world examples (without object at hand)
 - a) Concept of a frame—tying with relevant examples (physical photo frames); hand gestures forming a frame; need for framing—"why do we frame a picture?"
 - b) Concept of angles—pictures of how an object can be seen from different directions (explaining uses of 360 degree view without quoting the term "360 degrees")
 - c) Concept of distances—explaining how an object looks small/big from varying distances; how when you need to talk to somebody far, you go closer, etc.
 - d) Concepts of light—explaining how when the sun does not shine on the face, picture quality is usually bad; examples of photographs in bad light shown
 - e) Shot composition—explanation of long, mid and close-up shots with examples of photographs of the same object shot from different ranges
- 2) Demonstration of the object:
 - a) Introduction of the object by trainer, without exposing UI complexities
 - b) Applying all concepts (frame, light, angle, etc.) to object use by trainer
 - c) Demo of functions tied to concepts explained earlier
 - d) Demo repeated multiple times
- 3) Practice
 - a) Allowing the participant to touch and feel the object

- b) Group/collaborative do-it-yourself exercises for use of functions, with assistance from the trainer
- c) A group/collaborative do-it-yourself use of functions without assistance
- d) Spaced repetition of the exercises
- e) Shoot a short movie as a group (movie story provided)—apply concept of angles, framing, lighting, etc.
- f) Practice more number of movie shootings in a group
- g) Solo shooting exercises

The active training was for 3 weeks, and participants were able to operate the camera at the end of the training period. But learning to use the video camera effectively for shooting took up to 6 weeks of everyday usage. The term “effectively” is somewhat loosely used because the quality of the films shot definitely had scope for improvement. But the ability to operate the video camera to shoot a decent 5-7 minutes film was possible in this 6 weeks’ time frame.

Windows Moviemaker:

Teaching the Windows Moviemaker tool to participants none of whom had any previous experience with PC usage was challenging. An optimal teaching method for this tool is yet to be designed. 5 of the people who managed the use of the tool with almost no assistance at the end of the 3 weeks training period had education up to Grade X. These 5 people practiced for up to 8 weeks to edit 5-7 minute movies with basic effects and transition. Here’s a breakdown of the teaching process for this tool:

- 1) Concept explanation:
 - a) Explained how the different shots take from the video camera could be stitched together to make a whole (Video camera use taught before editing software)
 - b) Explained how the order of the shots could be interchanged.
- 2) Demo on the tool:

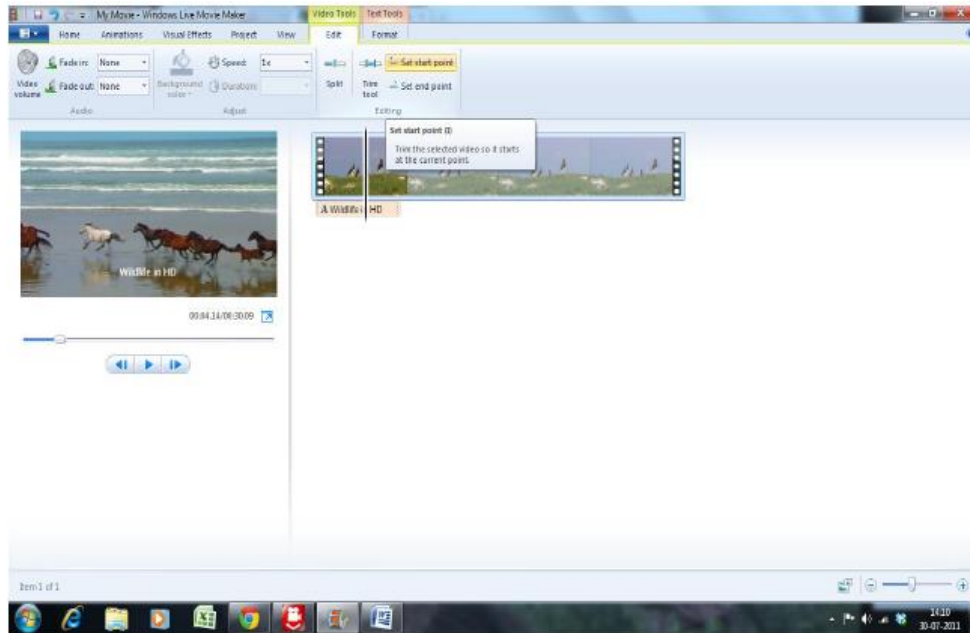
We were not able to identify what the most logical order for functions to be explained was, but we demoed various functions such as “splitting a shot”, adding audio track, adding titles, effects and transitions, adjustments of shot durations, etc. A number of demos for all these tool functions were conducted on multiple occasions within the 3 weeks training period.

4) Practice:

Use of this tool took a lot of hand-holding and practice during the 3 weeks training period.

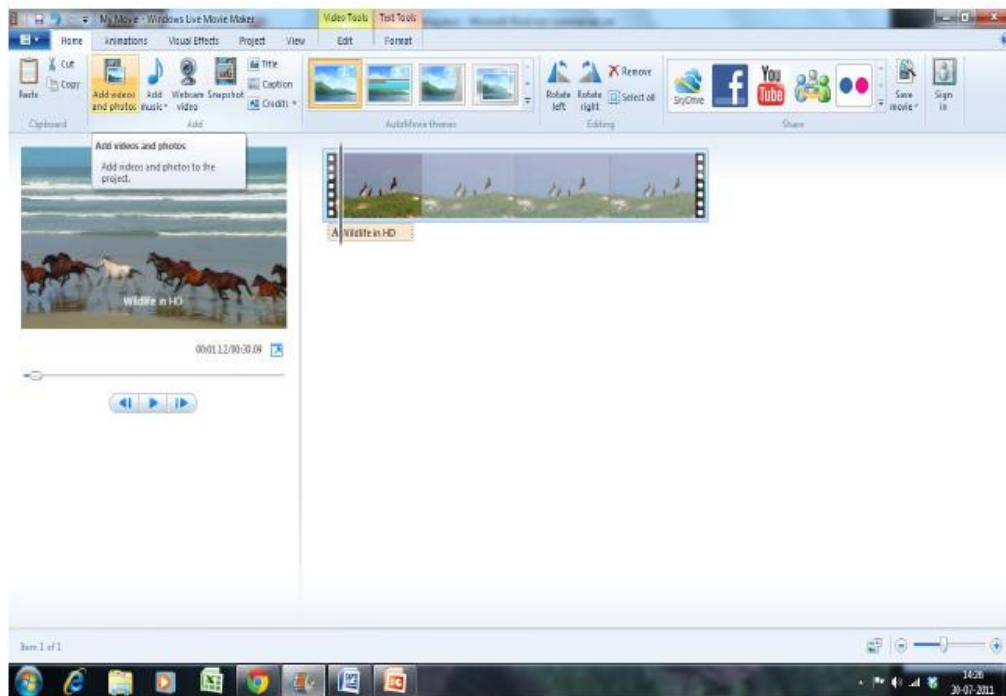
Appendix II

Excerpts from Video Editing Handout:



Step 4. By clicking 'edit' tab, you will find the following options in the drop down box:

- a) Video volume: - by clicking on the icon we can adjust the volume of a particular clip or whole video.
- a. One can also add effects in the audio such as voice "fade in" and "fade out" by clicking on the "fade in" "fade out" drop down box as shown in page 5.
- b) Split: By clicking on this button a given clip is split into two at the point where the sliding bar is situated. You can use this to create two clips out of one and also in cutting unwanted portions of a clip.
- c) Trim: This is used to "trim" a clip from the beginning and end of any given clip.
- d) "Set start point" and "set end point" by clicking on respective icons to determine the beginning and the ending of any clip or film.



Step 6. On clicking the 'Home' tab you will see the following options

a. Add video and photo :- Place the sliding bar where you desire to insert a particular video or photo and click on 'add video and photo' option and browse to the file you want to import and double click on the file. Your file will be imported and inserted where you want them to be.

b. Add music: - Click on this option and browse to the audio file and double click on it. Once the audio track is visible above the video file in your movie maker window, you can position it wherever you want it and accordingly edit the audio file too to synchronise with the video footage. (image on page 7)

c. Title, Caption and Credit: - By clicking on each of these options you can type the title in the beginning, type the caption anywhere you want and give credits at the end. By clicking on the text you can edit them to suit your needs. (image on page 7)

Appendix III

Specific video script from study I:

(English translation from Kannada):

Today we'll learn how to use a vacuum cleaner for our household cleaning work. First, pull out the cord from the opening behind the canister. Then plug in the vacuum cleaner by inserting plug into the wall socket. Then turn on the wall socket switch. Now locate the ON/OFF button. On pressing the button the vacuum cleaner turns on. Position the vacuum cleaner squarely at one end of the rug. Vacuum in a straight line by pushing the vacuum cleaner forward to arms' length and pulling the vacuum cleaner back slowly. Reposition the vacuum cleaner so as to vacuum parallel to area previously vacuumed. This is so that the whole carpet is covered. You can do this by moving the vacuum cleaner to the next part of the carpet correctly. Check that the whole carpet had been covered. Now let me show you how to use the different attachments to clean more effectively. Find the attachment here on the canister. Fit the attachment to the nozzle. With this attachment you can clean corners which may be otherwise difficult to reach. Now take off the attachment from the nozzle and put it back in the canister casing. To switch off the cleaner, press the ON/OFF button. Now switch off the wall socket and unplug the vacuum cleaner cord gently. Push this button to wind up the cord of the cleaner. Now let us see how to clean the vacuum cleaner bag which has accumulated dust and dirt. Locate the button to open lid, when you press the button the lid will open. Now slowly pull out the holder with the bag. You can pull out the bag by releasing the clip and throw away the bag. Take a new bag and slide it into the holder of the compartment. Now press close the lid. Your vacuum cleaner is ready for re-use.

Let us watch the instructions again. First, pull out the cord from the opening behind the canister. Then plug in the vacuum cleaner by inserting plug into the wall socket. Then turn on the wall socket switch. Now locate the ON/OFF button. On pressing the button the vacuum cleaner turns on. Position the vacuum cleaner squarely at one end of the rug. Vacuum in a straight line by pushing the vacuum cleaner forward to arms' length and pulling the vacuum cleaner back slowly. Reposition the vacuum cleaner so as to vacuum parallel to area previously vacuumed. This is so that the whole carpet is covered. You can do this by moving the vacuum cleaner to the next part of

the carpet correctly. Check that the whole carpet had been covered. Now let me show you how to use the different attachments to clean more effectively. Find the attachment here on the canister. Fit the attachment to the nozzle. With this attachment you can clean corners which may be otherwise difficult to reach. Now take off the attachment from the nozzle and put it back in the canister casing. To switch off the cleaner, press the ON/OFF button. Now switch off the wall socket and unplug the vacuum cleaner cord gently. Push this button to wind up the cord of the cleaner. Now let us see how to clean the vacuum cleaner bag which has accumulated dust and dirt. Locate the button to open lid, when you press the button the lid will open. Now slowly pull out the holder with the bag. You can pull out the bag by releasing the clip and throw away the bag. Take a new bag and slide it into the holder of the compartment. Now press close the lid. Your vacuum cleaner is ready for re-use.

Appendix IV

Diversified video script from study I

(English translation from Kannada):

Today we'll learn how to use two vacuum cleaners for our household cleaning work. For the first vacuum cleaner, pull out the cord from the opening behind the canister. Then plug in the vacuum cleaner by inserting plug into the wall socket. Then turn on the wall socket switch. Now locate the ON/OFF button. On pressing the button the vacuum cleaner turns on. Position the vacuum cleaner squarely at one end of the rug. Vacuum in a straight line by pushing the vacuum cleaner forward to arms' length and pulling the vacuum cleaner back slowly. Reposition the vacuum cleaner so as to vacuum parallel to area previously vacuumed. This is so that the whole carpet is covered. You can do this by moving the vacuum cleaner to the next part of the carpet correctly. Check that the whole carpet had been covered. Now let me show you how to use the different attachments to clean more effectively. Find the attachment here on the canister. Fit the attachment to the nozzle. With this attachment you can clean corners which may be otherwise difficult to reach. Now take off the attachment from the nozzle and put it back in the canister casing. To switch off the cleaner, press the ON/OFF button. Now switch off the wall socket and unplug the vacuum cleaner cord gently. Push this button to wind up the cord of the cleaner. Now let us see how to clean the vacuum cleaner bag which has accumulated dust and dirt. Locate the button to open lid, when you press the button the lid will open. Now slowly pull out the holder with the bag. You can pull out the bag by releasing the clip and throw away the bag. Take a new bag and slide it into the holder of the compartment. Now press close the lid. Your vacuum cleaner is ready for re-use.

For the second vacuum cleaner, unwind the cord from around the canister. Then plug in the vacuum cleaner by inserting plug into the wall socket. Then turn on the wall socket switch. Now locate the ON/OFF button. On pressing the button the vacuum cleaner turns on. Position the vacuum cleaner squarely at one end of the rug. Vacuum in a straight line by pushing the vacuum cleaner forward to arms' length and pulling the vacuum cleaner back slowly. Reposition the vacuum cleaner so as to vacuum parallel to area previously vacuumed. This is so that the whole carpet is covered. You can do this by moving the vacuum cleaner to the next part of the carpet correctly. Check that the whole carpet had been covered. Now let me show you how to use the different attachments to clean

more effectively. Find the nozzle secured here in the canister. With this attachment you can clean corners which may be otherwise difficult to reach. Now take the nozzle and put it back in the canister hold. To switch off the cleaner, press the ON/OFF button. Now switch off the wall socket and unplug the vacuum cleaner cord gently. Wind the cord around the canister. Now let us see how to clean the vacuum cleaner filter which has accumulated dust and dirt. Locate the button to take out the filter, when you press the button the filter will come out. Now take a brush and gently clean out the filter dust from all sides, like this. Once the filter is clean, set it back in the canister casing. Your vacuum cleaner is ready for re-use.

Appendix V

Videos watched and order in which the vacuum cleaner was presented in study I

See	Do		Category
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Familiar (1)	Unfamiliar (2)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate

Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Specific (1,1)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Familiar (1)	Unfamiliar (2)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate
Diversified (1,2)	Unfamiliar (2)	Familiar (1)	Non-literate

Appendix VI

Reading test- Standard I equivalent

ಓದುವುದು

೦. ಅಕ್ಷರಗಳನ್ನು ಗುರುತಿಸುವುದು

ಜ, ವ, ಮ, ಬ, ನ, ಲ, ಷ, ಈ, ಊ, ಕ

ಃ. ಪದಗಳನ್ನು ಗುರುತಿಸುವುದು

ಮರ' ಭಯ ಏತ'

ರಥ ಕವನ

ತುಂಟತನ ಓಡಾಡಿ ಅಕ್ಕ

ಹೋದನು ಸ್ನಾನ

ಅ. ವಾಕ್ಯಗಳನ್ನು ಓದುವುದು

1. ಬಾನಲಿ ಹಾರುವ ಗಾಳಿಪಟ

2. ಮುಖ ತೊಳೆದು ಹಾಲು ಕುಡಿದನು.

Reading test- Standard III equivalent

ಓದುವುದು

A. ವಾಕ್ಯಗಳನ್ನು ಓದುವುದು

1. ತುಂಬಿ ಹರಿಯುವ ನದಿ.

2. ಅದರ ತೀರದಲ್ಲಿ ನೇರಳೆ ಮರ.

3. ಮರದಲ್ಲಿ ಒಂದು ಕೋತಿ.

B. ವಾಕ್ಯಗಳನ್ನು ಓದುವುದು

1. ಮಿರಿಮಿರಿ ಮಿಂಚುವ ನೇರಳೆ ಹಣ್ಣುಗಳು ನೋಡಿದವರ ಬಾಯಿಯಲ್ಲಿ ನೀರೂರಿಸುತ್ತಿತ್ತು.

2. ಆ ಸವಿ ಹಣ್ಣುಗಳುನ್ನು ದಿನವೂ ತಿನ್ನುತ್ತ ಕೋತಿಯೊಂದು ಅಲ್ಲಿ ವಾಸವಾಗಿತ್ತು

3. ನದಿಯಲ್ಲಿರುವ ಮೊಸಳೆಗೆ ಆ ಹಣ್ಣು ತಿನ್ನುವ ಆಸೆ.

C. ಪಾಠ ಓದುವುದು

ರವಿ ಮತ್ತು ರಾಧಾ ಶಾಲೆಗೆ ಹೋಗುತ್ತಿದ್ದರು. ಪೀಟರ್ ಶಾಲೆಗೆ ಹೊರಟ. ರವಿ ಮತ್ತು ರಾಧಾ ಅವನಿಗಿಂತ ಮುಂದಿದ್ದರು. ಶಾಲೆಗೆ ಹೋಗುವುದು ತಡವಾಗುವುದು ಎಂದು ಭಾವಿಸಿದ. ಅವಸರವಾಗಿ ರವಿ ಮತ್ತು ರಾಧಾಳನ್ನು ಹಿಂಬಾಲಿಸಿದ. ರಸ್ತೆಯನ್ನು ದಾಟಲು ಆತುರದಿಂದ ಓಡಿದ.

D. ಪಾಠ ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರ ಹೇಳುವುದು

ರಮಾಗೆ ಎರಡು ದಿನಗಳಿಂದ ಆತಂಕ. ಅಂಚೆಯವನ ಸೈಕಲ್ ಶಬ್ದ ಕೇಳುತ್ತಲೇ ಓಡಿಬರುತ್ತಿದ್ದಳು. ಅವಳ ತಂದೆ ಶಂಕರಪ್ಪ ಕೇಳಿದ “ರಮಾ, ಯಾರನ್ನು ಕಾಯುತ್ತಿದ್ದೀಯಾ?”

ರಮಾ – “ಅಪ್ಪಾ, ಅಕ್ಕ ಮುಂಬಯಿಯಿಂದ ಚಿತ್ರ ಪುಸ್ತಕವನ್ನು ಅಂಚೆಯಲ್ಲಿ ಕಳಿಸುತ್ತೇನೆಂದು ಹೇಳಿದ್ದಳು. ಇನ್ನೂ ಬರಲಿಲ್ಲ ಅಪ್ಪಾ”. ಶಂಕರಪ್ಪ ಹೇಳಿದ “ಮೊದಲೇ ಹೇಳಬಾರದಿತ್ತೇ? ನಡೆ ಅಂಚೆಕಚೇರಿಯಲ್ಲೇ ವಿಚಾರಿಸೋಣ”.

- ರಮಾ ಯಾರಿಗಾಗಿ ಕಾಯುತ್ತಿದ್ದಳು?
- ರಮಾಳಿಗೆ ಪುಸ್ತಕವನ್ನು ಯಾರು ಕಳುಹಿಸಬೇಕಾಗಿತ್ತು?

Reading test- Standard V equivalent

ಓದುವುದು

೦. ಪಾಠ ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರ ಹೇಳುವುದು

ಆಟಗಳಲ್ಲಿ ಒಳಾಂಗಣ ಮತ್ತು ಹೊರಾಂಗಣ ಎಂಬ ಎರಡು ವಿಧಗಳು.

ಮನೆ ಅಥವಾ ಶಾಲೆಯ ಒಳಗೆ ಆಡುವ ಆಟಗಳು 'ಒಳಾಂಗಣ' ಆಟಗಳು. ಆಣೆಕಲ್ಲು, ಹಳಗುಣಿಮಣೆ ಆಟ, ಚೌಕಾಬಾರ, ಚಕ್ಕದಾಟ, ಹುಲಿಮನೆ - ಇವು ಒಳಾಂಗಣ ಆಟಗಳು. ಬಯಲಿನಲ್ಲಿ ಆಡುವ ಆಟಗಳು 'ಹೊರಾಂಗಣ' ಆಟಗಳು. ಕಣ್ಣುಮುಚ್ಚಾಲೆ, ಕುಂಟಾಟ, ಕುಂಟೆಬಿಲ್ಲೆ, ಕಲ್ಲೇಮಣ್ಣೋ, ಉಪ್ಪಿನ ಮನೆಯಾಟ, ರತ್ತೋರತ್ತೋ, ಕೊಕ್ಕೋ, ಸೆರೆಮನೆ ಆಟ, ಕಬಡ್ಡಿ, ಇವು ಹೊರಾಂಗಣ ಆಟಗಳು.

- ಆಟಗಳಲ್ಲಿ ಎಷ್ಟು ವಿಧಗಳಿವೆ?
- ಹೊರಾಂಗಣ ಆಟಗಳು ಯಾವುವು?
- ಒಳಾಂಗಣ ಆಟಗಳು ಯಾವುವು?

B. ಈ ಪದ್ಯವನ್ನು ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರಿಸಿ.

ನಾವು ಎಳೆಯರು ನಾವು ಗೆಳೆಯರು
ಹೃದಯ ಹೂವಿನ ಹಂದರ
ನಾಳೆ ನಾವೇ ನಾಡ ಹಿರಿಯರು
ನಮ್ಮ ಕನಸದೊ ಸುಂದರ

ಹಿಂದು ಮುಸ್ಲಿಂ ಕ್ರೈಸ್ತರೆಲ್ಲರಿಗೊಂದೆ
ಭಾರತ ಮಂದಿರ
ಶಾಂತಿದಾತನು ಗಾಂಧಿತಾತನು
ಎದೆಯ ಬಾನಿನ ಚಂದಿರ

ಜಾತಿ ರೋಗದ ಭೀತಿ ಕಳೆಯುತ
ನೀತಿ ಮಾರ್ಗದಿ ನಡೆವೆವು
ಒಂದೆ ಮಾನವ ಕುಲವು ಎನ್ನುತ
ವಿಶ್ವ ಧರ್ಮವ ಪಡೆವೆವು

ನಮ್ಮ ಸುತ್ತಲು ಹೆಣೆದು ಕೊಳ್ಳಲಿ
ಸ್ನೇಹಪಾಶದ ಬಂಧನ
ಬೆಳಕು ಬೀರಲಿ ಗಂಧ ಹರಡಲಿ
ಉರಿದು ಪ್ರೇಮದ ಚಂದನ

1. ನಾಳೆಯ ನಾಡ ಹಿರಿಯರು ಯಾರು?
2. ಎಲ್ಲರಿಗೂ ಇರುವ ಮಂದಿರ ಯಾವುದು?
3. ನಾವು ಯಾವ ಭೀತಿಯನ್ನು ಬಿಡಬೇಕು?
4. ಶಾಂತಿದಾತ ಯಾರು?

Reading test- Standard VII equivalent

ಓದುವುದು

ಪಾರಾ ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರ ಹೇಳುವುದು

A. ರಾಷ್ಟ್ರದ ಪ್ರಗತಿಯಲ್ಲಿ ಸ್ತ್ರೀಯರದು ಮಹತ್ವದ ಪಾತ್ರವಿದೆ. ಎಲ್ಲ ಕಷ್ಟ-ಸುಖ ಮತ್ತು ಜವಾಬ್ದಾರಿಗಳನ್ನು ಹೆಂಗಸರು ಹಂಚಿಕೊಳ್ಳಬೇಕೆಂದು ಮೇಡಂ ಕಾಮಾ ಪ್ರತಿಪಾದಿಸುತ್ತಿದ್ದಳು. ಈಜಿಪ್ಟಿನ ಒಂದು ಸಭೆಯಲ್ಲಿ ದೇಶದ ಅರ್ಧಭಾಗ ಮಾತ್ರ ನೋಡುತ್ತಿದ್ದೇನೆ ಇನ್ನರ್ಧ ಭಾಗ ಸಭೆಯಲ್ಲಿ ಭಾಗವಹಿಸಿಲ್ಲ ಏಕೆ ಎಂದು ಗಂಡಸರನ್ನು ಗಂಭೀರವಾಗಿ ಪ್ರಶ್ನಿಸಿದಳು. ಸುಮಾರು ಮೂರು ದಶಕಗಳಿಗೂ ಹೆಚ್ಚು ಕಾಲ ಪರದೇಶದಲ್ಲಿದ್ದುಕೊಂಡು ದೇಶದ ಸ್ವಾತಂತ್ರ್ಯಕ್ಕಾಗಿ ವಿಶ್ವದ ಸಹಾನುಭೂತಿ ಗಳಿಸಿದಳು. ಇದು ಮೇಡಂ ಕಾಮಾ ಅವಳ ಅತ್ಯಂತ ಮಹತ್ವದ ಕಾರ್ಯ.

- ಮೇಡಂ ಕಾಮಾ ರಾಷ್ಟ್ರದ ಪ್ರಗತಿಯಲ್ಲಿ ಯಾರ ಪಾತ್ರ ಮಹತ್ವದ್ದು ಎಂದು ಹೇಳಿದರು?
- ಮೇಡಂ ಕಾಮಾ ಅವರ ಅತ್ಯಂತ ಮಹತ್ವದ ಕಾರ್ಯ ಯಾವುದು?

B. ಕನ್ನಡ ನಾಡಿನಲ್ಲಿ 'ನಾಡಹಬ್ಬ' ಪರಂಪರೆಯಿಂದ ಬಂದದ್ದು. ವಿಜಯನಗರದ ಅರಸರು ಆರಂಭಿಸಿ ವೈಭವದಿಂದ ಆಚರಿಸುತ್ತಿದ್ದರು. ಮೈಸೂರು ದಸರಾ ಮಹೋತ್ಸವಕ್ಕೆ ನಾಡಹಬ್ಬವೇ ಮೂಲ. 'ನವರಾತ್ರಿ' ಎಂದೇ ಜನಮನದಲ್ಲಿ ಹಾಸುಹೊಕ್ಕಾಗಿದೆ. ಈ ಹಬ್ಬದಲ್ಲಿ ಶಕ್ತಿದೇವತೆಯನ್ನು ಪೂಜಿಸುವ ಪದ್ಧತಿ ಇದೆ. ಮೈಸೂರಿನ ಜಂಬೂಸವಾರಿ ವಿಶ್ವ ಪ್ರಸಿದ್ಧಿ. ಐತಿಹಾಸಿಕ, ಸಾಂಸ್ಕೃತಿಕ ವೈಭವವನ್ನು ಬಿಂಬಿಸುವ ದಸರಾ ಐಕ್ಯತಾ ಭಾವನೆಯ ಸಂಕೇತ. ಇದು ನಾಡಿನ ಹಿರಿಮೆಯನ್ನು ಸಾರುತ್ತದೆ. ಸಾಹಿತ್ಯ, ಕ್ರೀಡೆ, ಕಲೆ, ಸಮಾಜಸೇವೆಯಲ್ಲಿ ಅನುಪಮ ಸೇವೆಸಲ್ಲಿಸಿದ ಸಾಧಕರನ್ನು ಗೌರವಿಸುವ ಸತ್ ಸಂಪ್ರದಾಯ ಬೆಳೆದಿರುವುದು ಹೆಮ್ಮೆಯ ಸಂಗತಿ.

1. ನಾಡ ಹಬ್ಬವನ್ನು ಯಾರು ಆರಂಭಿಸಿದರು?
2. ಜನಮನದಲ್ಲಿ ನಾಡಹಬ್ಬ ಹೇಗೆ ಹಾಸುಹೊಕ್ಕಾಗಿದೆ?
3. ದಸರಾ ಯಾವುದರ ಸಂಕೇತ?
4. ಯಾವುದು ಹೆಮ್ಮೆಯ ಸಂಗತಿ?
5. ಪ್ರಬಂಧಕ್ಕೆ ಸೂಕ್ತ ತಲೆಬರಹ ಸೂಚಿಸಿ.

Writing test- Standard I equivalent

ಬರೆಯುವುದು (Dictation)

A. ಅಕ್ಷರಗಳನ್ನು ಬರೆಯುವುದು (Write letters)
ಕ, ರ, ಡ, ನ, ಯ

B. ಪದಗಳನ್ನು ಬರೆಯುವುದು (Write words)
ವನ ಸರ ಬಕ ಮತ
ಆಟ ಓಲಗ ಜಟಕ ಹವಳ

C. ಪದಗಳನ್ನು ಗುರುತಿಸುವುದು ಮತ್ತು ಬರೆಯುವುದು
(Identify & write words)
ಮರ ಹುಲಿ ಗಾಳಿಪಟ ತಬಲ

Writing test- Standard III equivalent

ಬರೆಯುವುದು

A. ಪದಗಳನ್ನು ಬರೆಯುವುದು (Write words)
ತಲುಪಬೇಕು ಗೌರವಿಸು ಕೀರಲು ಅಭಿಲಾಷೆ
ಚಪ್ಪಾಳೆ ಪ್ರೀತಿ ಸಮುದ್ರ

B. ವಾಕ್ಯಗಳನ್ನು ಬರೆಯುವುದು (Write sentences)

- ಶಾಲೆಯನ್ನು ಸಿಂಗರಿಸಬೇಕು
- ತಲಿರು ತೋರಣ ಕಟ್ಟಬೇಕು
- ಸ್ವಾತಂತ್ರ್ಯ ಪಡೆಯಲು ಹೋರಾಡಿದವರ ವೇಷ ಹಾಕಬೇಕು
- ಎಲ್ಲರಿಗೂ ಅವರ ನೆನಪು ಮಾಡಿಕೊಡಬೇಕು
- ದೇಶದ ಕನಸು ನನಸುಗಳ ಬಗ್ಗೆ ಮಾತನಾಡಬೇಕು

Writing test- Standard V equivalent

ಬರೆಯುವುದು

A. ವಾಕ್ಯಗಳನ್ನು ಬರೆಯುವುದು

1. ಗಾಯಕ ಸುಂದರವಾಗಿ ಹಾಡಿದನು.
2. ಜೋಗದಲ್ಲಿ ಸುಂದರವಾದ ಜಲಪಾತವಿದೆ.
3. ನಾವು ಎಂದೂ ಮೋಸ ಹೋಗಬಾರದು.
4. ಮುದುಕ ಮೆಲ್ಲಮೆಲ್ಲನೆ ನಡೆಯುತ್ತಾನೆ.
5. ರಾಣಿಗೆ ಒಬ್ಬ ಸೇವಕಿ ಇದ್ದಳು.
6. ದೇವಾಲಯದಲ್ಲಿ ರಥವು ಇದೆ.

B. ಪಾರಾ ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರ ಹೇಳುವುದು

ಇದೇ ಸುಂದರ ಜೋಗ ಜಲಪಾತ. ಇದು ಲೋಕ ವಿಖ್ಯಾತ. ಕನ್ನಡ ನಾಡಿನ ಹೆಮ್ಮೆಯ ತಾಣ. ಮಲೆನಾಡಿನ ಶಿವಮೊಗ್ಗ ಜಿಲ್ಲೆಯ ಸಾಗರ ತಲ್ಲೂಕಿನ 'ಜೋಗ' ಹಳ್ಳಿಯಲ್ಲಿದೆ. ಈ ಜಲಪಾತದಲ್ಲಿ ನಾಲ್ಕು ಧಾರೆಗಳಿವೆ - ಅವು ರಾಜ, ರಾಣಿ, ರೋರರ್ ಮತ್ತು ರಾಕೆಟ್.

- ಜೋಗ ಜಲಪಾತ ಎಲ್ಲಿದೆ?
- ಜೋಗ ಜಲಪಾತದ ಧಾರೆಗಳು ಯಾವುವು?

C. ಬಹುವಚನ ಬರೆಯಿರಿ :

1. ಹುಡುಗ
2. ಮರ
3. ಜನ
4. ನಾನು
5. ಆಟ

Writing test- Standard VII equivalent

ಬರೆಯುವುದು

A. ಪಾರಾ ಓದಿ ಪ್ರಶ್ನೆಗಳಿಗೆ ಉತ್ತರ ಬರೆಯುವುದು

ಇಂದು ದೇಶವು ಅನೇಕ ಸಮಸ್ಯೆಗಳನ್ನು ಎದುರಿಸುತ್ತಿದ್ದು ವಿಶೇಷವಾಗಿ ಭಯೋತ್ಪಾದಕತೆ ದೇಶದ ಅಭಿವೃದ್ಧಿಗೆ ಮಾರಕವಾಗಿದೆ. ಹೊರಗಿನ ಉಪದ್ರವ ಒಂದಾದರೆ, ಆಂತರಿಕ

ಸಮಸ್ಯೆಗಳು ಇನ್ನೊಂದೆಡೆ. ನೆಲ, ಜಲ, ಭಾಷೆ, ಧರ್ಮ, ಪ್ರಾದೇಶಿಕ ಅಸಮತೋಲನ ಮುಂತಾದ ಭಾವನಾತ್ಮಕ ಸಮಸ್ಯೆಗಳು. ಒಮ್ಮೊಮ್ಮೆ ದೇಶದ ಐಕ್ಯತೆ ಮತ್ತು ಸಮಗ್ರತೆಗೆ ಸವಾಲೊಡ್ಡುತ್ತಿತ್ತು. ಇಂತಹ ಸಂದರ್ಭಗಳನ್ನು ಎದುರಿಸಲು ತರುಣರಿಗೆ 'ರಾಷ್ಟ್ರ ಜೀವನ'ದ ತರಬೇತಿ ಅತ್ಯಗತ್ಯ.

೧. ಭಾರತಕ್ಕೆ ಯಾವ ಸಮಸ್ಯೆಗಳು ಸವಾಲೊಡ್ಡುತ್ತಿವೆ?
೨. ತರುಣರಿಗೆ ಇಂದು ಬೇಕಾದ ತರಬೇತಿ ಯಾವುದು?

B. ವಿರುದ್ಧಾರ್ಥಕ ಪದ ಬರೆಯಿರಿ :

1. ಬಡತನ - ಸಿರಿತನ
2. ನೋವು - ನಲಿವು
3. ದುಃಖ - ಸುಖ
4. ಪೂರ್ವ - ಪಶ್ಚಿಮ
5. ಭಿನ್ನಾಭಿಪ್ರಾಯ - ಸಮಾನಾಭಿಪ್ರಾಯ

C. ಸ್ವಂತ ವಾಕ್ಯಗಳಲ್ಲಿ ಈ ಪದಗಳನ್ನು ಉಪಯೋಗಿಸಿ ವಾಕ್ಯ ರಚಿಸಿ ಬರೆಯಿರಿ :

1. ಕಣ್ಣು -
2. ಆಹಾರ -
3. ಹಾರುವುದು -
4. ಪ್ರಾಮಾಣಿಕ -
5. ಹೋರಾಟ -

Appendix VII

Tools considered for assessment of the ability for non-verbal abstract reasoning, other than Raven's Progressive Matrices:

We studied a number of tools that might be used as a proxy for measuring abstract thinking:

- The California Proverbs test (Gorham, 1956): It measures degrees of concrete/abstract (non-literal) interpretation of a proverb: Correct abstract response, correct nuance response, partial abstract response, correct concrete response, correct reiteration response, etc.
- Mednick's remote associates test (Mednick, 1962): it requires participants to think of a fourth word (through association and understanding of relationships) that relates to each of the three "clue" words in a series.

One observation was that none of these above tools seemed formal education-neutral—e.g. proverbs are something one learns in school and the tests would be biased in favour of our "textually-literate" test participants. Likewise for the remote associates test, one needs a good range of vocabulary to take this test.

We found two additional tools that seemed relevant at that time:

- Draw a person test (Goodenough, 1926; Harris, 1963): To measure the cognitive developmental stage of an individual. The participant is required to complete three individual drawings on separate pieces of paper-- a man, a woman, and themselves. This system analyzes fourteen different aspects of the drawings for various criteria, including presence or absence, detail, and proportion.
- Duncker's candle test for "functional fixedness" (Duncker, 1945): Tests for a cognitive bias that limits a person to using an object only in the way it is traditionally used. "Functional fixedness" has been defined as being a "mental block against using an object in a new way that is required to solve a problem." This "block" then limits that ability of an individual to use the components given to them to make a specific item, as they cannot move past the original intention of the object. Participants are given a candle, a box of thumbtacks, and a book of matches, and asked to attach the candle to the wall so that it did not drip onto the table below.

The issue here was that the two above tools intuitively did not seem to measure a reasonable proxy for our definition of non-verbal abstract reasoning. Based on all these observations, we decided to go ahead with an adapted version of Raven's progressive matrices as the proxy.

Appendix VIII

Text position map of the list UI on the PC:

Shorts	Shirt	Pants	Dhoti	Dress	Skirt	Salwaar kameez	Saree	Blouse
Petticoat	Half saree	Baby clothes	Baby napkin	TV	Toaster	DVD player	Speakers	
Microwave	Mixer-grinder	Necklace	Anklet	Ring	Maang tikaa	Bangles	Nose ring	
Toe rings	Earrings	Cricket	Carrom	Football	Ludo	Tumbler		
Karahi	Frying pan	Bowl	Pressure cooker	Bucket	Plate	Water pot		

Appendix IX

Verbal instructions before start of the PC UIs tests:

Today we'll play a game of finding items on the computer. You'll use the computer and this computer pen that I'm holding. You'll have to find 5 items through this game. There will be pictures for each of these items. I'll name the items one by one when you've started playing.

1) (For list):

Okay, then let's start now. You just need to point to the item that I'll name, on this screen, with this computer pen. Okay, so the first item to you need to find is...

2) (For shallow/deep hierarchy):

Before you use the computer we'll watch a video on how to use it. If you want to watch the video again, please let me know. You can watch it to a maximum of three times. The video has details for how to hold this computer pen and press on the computer screen. Then by going from one screen to another by pressing with this pen as required, you should be able to find the items you're looking for. Okay, now let's watch the video.

(Show video) Do you want to watch the video again? Please tell me if you do, because once you've started playing the game, you'll be on your own. I won't be able to help you.

(Show video) up to 3 times if participant requests.

Okay, now you've watched the video for how to find animals and birds through the computer game. Do you remember what you saw? Now you'll use this computer pen in a similar manner as the video, to find household items on the game that you'll play. Okay, so the first item to you need to find is...

Appendix X

Script of the instructional video shown before use of the shallow/deep hierarchy on the PC:

Facilitator (F) to User (U): Have to ever used a computer?

U to F: No, I haven't, never.

F to U: Okay, then shall we play a computer game today? It's a very simple game. I'll show you how.

U to F: Okay, sound good.

F to U: Now on this computer game, you'll have to find the picture of a lion. Now between these two pictures (group of animals, group of birds), under which category will you find the picture of the lion and its cub?

U to F: (Pointing to the group of animals) I'll find it here.

F to U: Why will you find it here?

U to F: Because lion is not a bird, it's an animal, that's why I'll find it here (pointing to the group of animals). But what should I do to find it here?

F to U: I'm giving you this computer pen. Now with this computer pen, you can touch the computer screen like this. You can press it on your answer, okay? Would you like to try it?

U touches the picture of group of animals with stylus. She's taken to a screen with two pictures, one showing a house, the other showing a forest.

U to F: Lion is a wild animal, so I'll find it in the jungle (presses photo of the jungle with stylus. Screen changes, she's taken to a screen with three pictures: a lion with a cub, two foxes, and one zebra.)

U to F: (Pointing to the picture of the lion with cub) Yay, here's the lion with cub! This is what I want.

F to U: Very good, very good. You've done very well. Now try to find a picture of a duck.

U to F: Duck is a bird, how will I find it here?

F to U: You remember that screen, with the pictures of a group of animals and a group of birds. You'll need to go there.

U to F: How will I go there?

F to U: (Pointing at the back arrow) Here's a blue color back arrow, do you see it? Now you'll need to use the pen and press on it. (User presses, screen changes to a picture of a house and a forest). Did it work? Press it again here. (Screen changes to one with a group of animals and a group of birds).

U to F: Oh wow, nice!

F to U: Now where will you press?

U to F: I'll press on the picture of the group of birds (Presses on picture, screen changes to one with a house and open skies over trees).

F to U: Now where will you press?

U to F: (Pressing on the picture of the house) A duck is a domestic bird, so. (Screen changes to one with a hen, a pigeon and a duck). Yay! Here's the duck.

F to U: Very good. Bravo! You did very well.

Appendix XI

Verbal instructions before start of the mobile UIs tests:

Today we'll play a game of finding items on the mobile phone. You'll use the phone to find 5 items through this game. There will be pictures for each of these items. I'll name the items one by one when you've started playing.

Before you use the mobile phone we'll watch a video on how to use it. If you want to watch the video again, please let me know. You can watch it to a maximum of three times. The video has details for how to touch the mobile phone screen. Then by going from one screen to another by pressing as required, you should be able to find the items you're looking for. Okay, now let's watch the video.

(Show video) Do you want to watch the video again? Please tell me if you do, because once you've started playing the game, you'll be on your own. I won't be able to help you.

(Show video) up to 3 times if participant requests.

Okay, now you've watched the video for how to find animals and birds through the mobile phone game. Do you remember what you saw? Now you'll use this phone in a similar manner as the video, to find household items on the game that you'll play. Okay, so the first item to you need to find is...

Appendix XII

Script of the instructional video shown before use of the list on the mobile phone:

Facilitator (F) to User (U): Have you ever used a mobile phone?

U to F: Yes, yes, I have.

F to U: In this phone, you have to press on the screen itself to go from one to another. Have you used such a mobile phone?

U to F: No, I don't think I have used that kind of a phone.

F to U: No problem, I'll give you such a phone. You'll have to press on the screen itself to go from one to another. (Handing over phone) Here's the phone, do you see pictures here? Let's play a game of finding items on the phone. Can you find me a picture of a lion with a cub?

U to F: (Pointing to lion picture on first page) Here it is, here's the lion with the cub!

F to U: Ok good, good, now can you find me the picture of a duck?

U to F: But I don't see the picture of a duck here (on the first screen). What do I do?

F to U: Do you see this blue color arrow here (pointing to the arrow)? Press this arrow. There'll be more such pictures.

U to F: Is it? (Pressing the arrow, screen changes to second screen) But even this page does not have a picture of the duck.

F to U: It's not here, right? Press the forward arrow again to check in the next screen?

U to F: (Pressing the arrow, screen changes to third screen) Yay, here is the duck!

F to U: Great, wonderful! Now can you find me the picture of a dog?

U to F: But there's no picture of a dog on this screen. What should I do?

F to U: So far you were pressing the forward arrow. Do you see the back arrow on this screen? (Points to the back arrow.) You have to press this arrow to go back.

U to F: Oh okay. (Presses the back arrow. Screen changes to second screen). Yay, here's the dog!

F to U: Very good, you did very well.

Script of the instructional video shown before use of the deep hierarchy on the mobile phone:

Facilitator (F) to User (U): Have you ever used a mobile phone?

U to F: Yes, yes, I have.

F to U: In this phone, you have to press on the screen itself to go from one to another. Have you used such a mobile phone?

U to F: No, I don't think I have used that kind of a phone.

F to U: No problem, I'll give you such a phone. You'll have to press on the screen itself to go from one to another. (Handing over phone) Here's the phone, do you see pictures here? Of groups of animals and birds? Let's play a game of finding items on this phone. Can you find me a picture of a lion with its cub? Where will you find a picture of the lion with its cub—under the group of animals or the group of birds?

U to F: Mmm, lion is not a bird, it's an animal. So I'll find it under here (pointing to the picture of the group of animals).

F to U: Yes, press that picture.

U presses the picture of group of animals. She's taken to a screen with two pictures, one showing a house, the other showing a forest.

U to F: Lion is a wild animal, so I'll find it in the jungle (presses photo of the jungle. Screen changes, she's taken to a screen with three pictures: a lion with a cub, two foxes, and one zebra.)

U to F: (Pointing to the picture of the lion with cub) Yay, here's the lion with cub! This is what I want.

F to U: Very good, very good. You've done very well. Now try to find a picture of a duck.

U to F: Duck is a bird, how will I find it here?

F to U: You remember that screen, with the pictures of a group of animals and a group of birds. You'll need to go there.

U to F: How will I go there?

F to U: (Pointing at the back arrow) Here's a blue color back arrow, do you see it? Now you'll need to press on it. (User presses, screen changes to a picture of a house and a forest). Did it work? Press it again here. (Screen changes to one with a group of animals and a group of birds).

U to F: Oh wow, nice!

F to U: Now where will you press?

U to F: I'll press on the picture of the group of birds (Presses on picture, screen changes to one with a house and open skies over trees).

F to U: Now where will you press?

U to F: (Pressing on the picture of the house) A duck is a domestic bird, so. (Screen changes to one with a hen, a pigeon and a duck). Yay! Here's the duck.

F to U: Very good. Bravo! You did very well.

Appendix XIII

Raw data from Study II

Literacy Score	Weighed Literacy	Raven	UI	Correct Responses	%Correct	TimeCorrect	MeanTime
0	0	3	L	5	100	296	59.2
0	0	2	D	2	40	110	94
0	0	2	D	4	80	274	78.8
0	0	0	S	2	40	27	77.4
0	0	3	D	0	0		120
0	0	2	S	5	100	87	17.4
0	0	0	D	1	20	85	113
0	0	2	S	4	80	180	60
0	0	3	L	4	80	122	48.4
0	0	2	D	1	20	114	118.8
0	0	1	D	2	40	123	96.6
0	0	5	L	5	100	86	17.2
0	0	1	L	4	80	64	36.8
0	0	2	L	4	80	287	81.4
1	1	1	S	3	60	314	110.8
7	57	1	L	4	80	210	66
7	57	3	D	0	0		120
10	10	3	S	4	80	477	119.4
17	67	1	S	3	60	80	64
18	68	5	L	5	100	33	6.6
18	168	6	S	5	100	46	9.2
19	119	1	S	5	100	162	32.4
19	169	7	D	5	100	237	47.4
19	119	4	D	1	20	45	105
20	70	4	L	4	80	87	41.4
20	170	3	S	4	80	262	76.4
20.5	120.5	1	D	3	60	85	65
21	171	4	S	5	100	57	11.4
22	72	5	L	5	100	220	44
22	172	5	S	5	100	356	71.2
24	24	3	S	4	80	132	50.4
24	124	2	D	0	0		120
24.5	124.5	1	S	4	80	144	52.8
24.5	24.5	5	S	5	100	420	84
24.5	24.5	2	D	4	80	422	108.4
26	76	2	S	5	100	146	29.2

26	26	4 L	5	100	295	59
26	126	4 S	5	100	179	35.8
27	177	6 D	5	100	391	78.2
27	77	4 D	2	40	176	107.2
28	178	5 L	5	100	16	3.2
32	182	9 D	3	60	201	88.2
32.5	182.5	10 S	5	100	23	4.6
34.5	184.5	6 L	5	100	53	10.6
35	85	3 S	5	100	60	12
36	86	5 D	3	60	271	102.2
36	186	4 D	4	80	148	53.6
38.5	188.5	4 D	5	100	483	96.6
39	189	7 L	5	100	12	2.4
39	189	7 S	5	100	120	24
40	90	7 L	5	100	138	27.6
40	190	5 L	5	100	24	4.8
40.5	190.5	8 D	5	100	245	49
41	141	6 L	5	100	119	23.8
42	142	5 D	3	60	209	89.8
42	192	7 D	5	100	176	35.2
43	193	8 L	5	100	67	13.4
43	143	2 S	4	80	143	52.6
44	194	8 S	3	60	38	55.6
47	197	8 L	5	100	24	4.8

Appendix XIV

Raw data from the follow-up Study III

Users on the phone hierarchy:

Correct responses	Average correct	Time Correct	Average time taken
3	0.6	180	84
2	0.4	46	81.2
3	0.6	190	86
5	1	264	52.8
5	1	237	47.4
5	1	204	40.8
4	0.8	198	63.6
5	1	141	28.2
4	0.8	331	90.2
4	0.8	282	80.4

Users on the phone list:

Correct responses	Average correct	Time Correct	Average time taken
5	1	63	12.6
5	1	175	35
5	1	296	59.2
5	1	73	14.6
5	1	111	22.2
5	1	235	47
5	1	48	9.6
5	1	43	8.6
5	1	89	17.8
5	1	117	23.4

Appendix XV

Raw data from the Study I

Prompts required by participants to complete tasks across all conditions:

Specific-Familiar-Lit	Specific-Familiar-Non-Lit	Diversified-Familiar-Lit	Diversified-Familiar-Non-Lit	Specific-Unfamiliar-Lit	Specific-Unfamiliar-Non-Lit	Diversified-Unfamiliar-Lit	Diversified-Unfamiliar-Non-Lit
7	20	6	22	25	18	5	25
4	9	21	19	16	22	26	16
26	8	13	1	29	8	22	8
4	3	49	28	19	12	54	18
8	6	45	17	9	5	51	24
25	13	18	39	17	11	28	42
3	8	24	33	13	8	18	34
13	13	24	14	16	11	34	19
16	14	38	26	30	19	30	47
17	9	8	29	17	17	19	26
15	9	18	38	23	12	23	26
9	2	24	25	21	7	25	18
7	11	23	28	19	15	21	21
16	12	32	42	12	22	38	38
12.14	9.78	24.5	25.78	19	13.35	28.14	25.85

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