DISPLAY COMPUTERS

A Dissertation

by

LISA MIN-YI CHEN SMITH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2006

Major Subject: Computer Science

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Approved by:

Chair of Committee, John J. Leggett
Committee Members, Richard Furuta
Taeg Nishimoto
Frank Shipman
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ABSTRACT

Display Computers. (May 2006)
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A Display Computer (DC) is an everyday object: Display Computer = Display + Computer. The "Display" part is the standard viewing surface found on everyday objects that conveys information or art. The "Computer" is found on the same everyday object; but by its ubiquitous nature, it will be relatively unnoticeable by the DC user, as it is manufactured "in the margins". A DC may be mobile, moving with us as part of the everyday object we are using. DCs will be ubiquitous: "effectively invisible", available at a glance, and seamlessly integrated into the environment. A DC should be an example of Weiser's calm technology: encalming to the user, providing peripheral awareness without information overload. A DC should provide unremarkable computing in support of our daily routines in life. The nbaCub (nightly bedtime ambient Cues utility buddy) prototype illustrates a sample application of how DCs can be useful in the everyday environment of the home of the future. Embedding a computer into a toy, such that the display is the only visible portion, can present many opportunities for seamless and non-traditional uses of computing technology for our youngest user community. A field study was conducted in the home environment of a five-year old child over ten consecutive weeks as an informal, proof of concept of what Display Computers for children can look like and be used for in the near future. The personalized nbaCub provided lightweight, ambient information during the necessary daily routines of preparing for bed (evening routine) and preparing to go to school (morning routine). To further understand the child's progress towards learning abstract concepts of time passage and routines, a novel "test by design" activity was included. Here, the role of the subject changed to primary designer/director. Final post-testing showed the subject

knew both morning and bedtime routines very well and correctly answered seven of eight questions based on abstract images of time passage. Thus, the subject was in the process of learning the more abstract concept of time passage, but was not totally comfortable with the idea at the end of the study.

dedicated to

Keegan, Zachary, and Lexie

with all my love

ACKNOWLEDGEMENTS

First and foremost, I wish to thank Dr. John J. Leggett, the chair of my advisory committee. He provided the initial vision and direction, always encouraging me to "tell a story". Fortunately for me, he also exhibited the great patience to read the story: reviewing endless pages of lit reviews, proposals, IRB applications, and my final dissertation. I never knew I had the ability to think "out of the box" until I started working with Dr. Leggett.

I also wish to thank Dr. Richard Furuta, another member of my committee. After two semesters of classes, it was inevitable I would learn to read, write, and speak better -- while developing the necessary skills to summarize, analyze, and present on a short timeline. Special thanks Dr. Frank Shipman and Dr. Taeg Nishimoto, for taking the time to serve on my doctoral committee and keeping an open mind in support of my unconventional research subject and study.

I would also like to thank Dr. Bart Childs and Dr. Donald Friesan for always offering their assistance whenever asked, during both of my tenures as a computer science graduate student at Texas A&M University. To the members of the Institutional Review Board – Human Subjects in Research, Texas A&M University, chaired by Dr. Alvin Larke Jr., thank you for sharing your interest and enthusiasm regarding my proposed study after reviewing my research protocol.

Dr. Mansur Samadzadeh of Oklahoma State University served as my committee chair during work on my Master of Science degree in Stillwater. I wish to thank him for providing me with a foundation on which to continue my studies at Texas A&M University. Thanks to him, I sharpened my skills of attention to detail and was conditioned to be fearless around the color of red ink.

My appreciation goes to the following computer science faculty members at Sam Houston State University in Huntsville: Dr. David Burris, Dr. Peter Cooper, Dr. Tim McGuire, and Dr. Gary Smith. I appreciate the interest you have shown in my studies over the last couple of years. Also from Sam Houston State University, I thank Mrs. Cindy Truax, my former supervisor at University Advancement. Four years ago she graciously wished me well as I left my job to pursue another career path. She has continually encouraged me to keep my eye on the ball and complete my degree.

A special thank you to Pham's Alterations in Huntsville, for expertly modifying the nbaCub form factor to securely hold a PDA. No words can express my gratitude to the local family who volunteered to participate in a ten-week research study. I really appreciate the time and effort the family spared on my behalf.

Special thanks goes to the Chen family, the Huang family, the Smith family, and the Twedell family. You have supported my return to school with nothing but encouragement. I salute the Drs. who have preceded me: Dr. Linda Chen, my mother; Dr. Audrey Chen, my sister; Dr. James Smith, my father-in-law; and last but not least, Dr. Gary Smith, my husband. The fact that you have all gone through the experience of earning your doctorates, lets me know I can do the same, and inspires me to do so.

To Mrs. Margaret Chao of Lake Forest, California, you hold the title of "best mother" by a long shot. Your unwavering support for everything I do is very much appreciated and never taken for granted. You always know how to remind me what is most important in life.

Most of all, I wish to acknowledge my kids, Keegan, Zachary, and Lexie: you challenge me and amaze me every day of my life. I thank you for being you. Always remember, you are the best!

For almost three decades, personal computers (PCs) have been part of the computing infrastructure, bringing the power of word processing, spreadsheet and database applications into the home. Portable computers and laptops have allowed professionals to take their PCs ‘on the road.’ More recently, Personal Digital Assistants (PDAs) have offered calendar and time management applications for the busy professional. The emerging new tablet computers augment laptops with slimmer and lighter form factors and note-taking/annotation applications, and promise to usher in a new computing revolution.

Impressive as the current penetration of computing is into the fabric of everyday life, it will pale in comparison to the coming revolution brought on by Display Computers (DCs). DCs are so named because, to the average person, they are simply displays. The physical size of the display vis-à-vis the physical size of the human will allow for the computer, wireless networking, and storage to be manufactured ‘in the margins’. New low-power, thin, light, and bright displays will become the standard viewing surface throughout the workplace and the home.

-- John Leggett [117]

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1. INTRODUCTION

The term Display Computer (DC) at first glance seems easy enough to define: Display Computer = Display + Computer. The "Display" part is the standard viewing surface found on everyday objects that conveys information or art and is found in everyday environments, indoors or out. The "Computer" is found on the same everyday object, but by its ubiquitous nature, it will be relatively unnoticeable by the DC user, as it is manufactured "in the margins" [117].

Some fundamental characteristics of Display Computers are also easy to list. A Display Computer is a mobile computer [121], it moves with us as part of the everyday object we are using. A DC is a ubiquitous computer: "effectively invisible" [217], available at a glance, and seamlessly integrated into the environment [218, 219]. A DC should be an example of Weiser's calm technology [223, 224]: encalming to the user, providing peripheral awareness without information overload. A DC should provide unremarkable computing in support of our daily routines in life [202].

But Display Computing requires a totally different way of thinking. It is difficult to disregard our learning and experience with the traditional desktop metaphor. This is not a new problem in the history of Visionary Computing. Researchers who chose to follow the visionary ideas of the past have always had to learn to think in radically different ways.

This dissertation attempts to define what we envision to be the future of Display Computers and what they can do for us. Display Computers are for everyday people in everyday environments. For this reason, we have chosen to focus our work on families.

This dissertation follows the style of *Communications of the ACM.*

What will mom and pop need in their everyday environment to make their lives easier and more enjoyable, hopefully leaving them more time to spend with the kids? What will children need to help them learn and be full participants in all of their multiple environments?

Current research and development efforts will lead to advances in fabrication methods and new technologies that will make DCs possible. When these technologies become affordable enough to mass market to the general public, our world will change right before our eyes. Novel form factors to deliver unique applications will be commonly available with the advent of Display Computers. These new paradigms of use are based on the needs of the Display Computer users: the children, parents, and extended members of families. As Shneiderman suggests in his book entitled *Leonardo's Laptop*, "visionary insights come from thinking more about human needs than technological possibilities" [185].

1.1 Display Computers

Display Computers are for everyone. No one will be left behind. If you can "see" a Display Computer, you can access it. Currently, the World Wide Web offers those with Internet access and the proper computer equipment the opportunity to sit at their computer to "surf" the Internet for information from any web site. However, the required resources of "access" and "equipment" are limiting factors in our current society. For various reasons, many people are left out. In the future world of DCs, the traditional computer will still be available but will not be required for everyday people to participate in the information revolution.

Everyday actions of people can be simplified in the following way:

1. To learn about the world, archive, and retrieve this information for later use by themselves or to share with others.
2. To participate in the world, archive, and retrieve their memories for later enjoyment or review by themselves or to share with others.

These everyday actions are commonly based on long-term individual goals, and ideally towards the contribution and benefit of human society as a whole. As technology changes, the needs of everyday people will not change. However the way information is displayed and accessed, and memories are archived and retrieved by individuals will dramatically change.

A DC as an everyday object. Eventually everyday objects in our daily environment that surround us and provide us information, be it text or visual images, will have the potential to become computers that provide us with a vast array of functionality we do not yet expect or understand. Ordinary people will recognize them simply as displays -- displays of information or art. However, these Display Computers will have computers embedded on them, unseen and unnoticed by the viewer.

A DC as an information display surface. All the ways we currently use to display information via text or images in our everyday environment can potentially be transformed into a DC. In addition, many new surfaces will emerge as DC-compatible, thus saturating our everyday spaces for living and working -- and all the places in between.

A DC as an information source. Most people have the ability to “read” static text from all types of information sources as long as they are close enough to see it. To save it for future reference, one may make a mental note of it, write a note on a physical piece of paper, make a photocopy, or ideally, save it to a file on a computer. With the advent of

DCs, the ability to access and "read" digital information from the same aforementioned static text sources plus many more will be possible. For all practical purposes, every DC physically encountered in the course of the day would be a potential source of information to be "read" or accessed. In addition, one should be able to save and retrieve the information for later review.

A DC as an information management tool. Masquerading as everyday objects, DCs will saturate the everyday environment -- indoors in the home, at work, and in the community and outside in the natural environment. At every point a DC is visible, people should be able to access the particular information published there, then display or archive the specific parts that interest them to a DC they are carrying or wearing, depending on their need at the moment.

For example, the actual physical highway we drive along where we see road signs, advertising billboards, store signs, etc., will literally become part of the future "information highway", along with every other DC we come across during our daily activities. No longer will one be required to sit in front of the computer to access publicly available information. Instant access to relevant information while being mobile during the performance of everyday activities in everyday environments will become a viable option for every member of society.

A DC as a memex. To "augment" human memory, DCs will offer everyone a way to wear or carry their own "memex" [25] in a natural and unobtrusive manner. As they move about their daily environment, they should be able to collect information in a lightweight manner at the instant they deem it pertinent or interesting in relation to their current or future goals.

A DC as a digital library. In a sense, this will mean the ability to create "reverse" digital libraries (DL). In a traditional digital library, we strive to digitize the real world and organize it into meaningful libraries that can be accessed by the public (or the few with access privileges), commonly from a different geographic location through the Internet. Digital library users must first come to an understanding of what the DL collection contains [30] before they can meaningfully peruse the library content to find the information they are seeking.

However, in the future world of DCs, the DC user will already know the content at the high level, simply because they will be in total control to choose the information and thus build their own DL based on their own experiences and interests. They should literally be able to walk or drive around, and access and archive any content of interest to add to their own individual, personalized digital library. New computer-human interaction technologies will support the access, archival, and retrieval processes between the DC they are wearing or carrying (destination) and the DC (source) they are looking at.

A simple analogy can be taken from the current world of computer gaming. Players are represented by avatars, which travel in the game environment picking up things or performing activities at particular places to earn points. In the DC world, we will be the avatars walking around in our own real world to pick up information that meets our personal interests and needs. We can accomplish this through the Display Computers that will surround us in our everyday life.

Current research and development efforts will lead to advances in fabrication methods of new technologies that will make DCs possible. When these technologies become affordable enough to mass market to the general public, our world will change right before our eyes.

For example, organic light-emitting diodes (OLEDs) are expected to provide competition for the market of computer monitors currently available using cathode ray tube (CRT) or flat-panel liquid crystal displays (LCDs) when their fabrication becomes cheap enough to be affordable to the average consumer. The innovation is that OLEDs will offer displays that are paper-thin, flexible, brighter, and require much less power. They can be sprayed on any sized surface such as cloth or plastic substrates and cut, folded, or rolled up [230, 69, 193, 137].

1.2 The DC World

The DC World is the physical world we live in. The DC world is made up of the places we choose to come into physical contact with everyday. It is the natural environment that is available to us when we physically travel from one location to the other, by whatever means we wish to get there: walking, running, biking, driving, riding, swimming, flying…

It is the inside and outside of our homes, the buildings or campuses where we work or study, the schools and venues our children go to learn or participate in extracurricular activities. These are the places we go everyday: from our home in the morning to places in our local community and back home again at night. If the need arises or time permits, we will travel beyond the local community to other communities, states, or countries. Everywhere we go in the course of living our daily life during our lifetime is included in our DC world.

Our DC world is defined by the entire path of our daily trip, from our initial departure point to the final destination, and all the places in between. Perhaps everyday our DC world is the same -- illustrating an unchanging routine. Perhaps everyday our DC world is different, where each day brings new opportunities to travel a different route to a new destination.

However, what our DC world is not, is the virtual world of the World Wide Web that can only be accessed through the Internet by a computer. Not that this virtual world is unneeded or unappreciated. Far from it. For many of us, we rely on it daily for information and communication with other people and places in our world. However, to access this virtual world, we generally need to have several components at our disposal: a computer with the required software and associated input/output peripheral devices, and wired or wireless access to the World Wide Web through an Internet Service Provider. All of these components may not be readily available to us during the course of the day, depending on where we are exactly in our world. To many people in the world, none of these components have ever been available. For these people and for us, however, the DC world will always be available, anywhere and everywhere, at any time of the day or night.

Our DC world consists of all the display surfaces we can see, smell, and touch in all the different environments we come to be in, everyday of our lives. This dissertation attempts to define what we envision to be the future of Display Computers and what they can do for us.

2. LITERATURE REVIEW: SIX DECADES OF VISIONARY COMPUTING

The term “paradigm” was first used as a means “to express an alternative concept of the history of science to that of the dominant beliefs of the time” [67]. Events in the history of computing, as we have come to know it today, are generally marked along a computer technology timeline. The initial advances in hardware platforms were commonly available to research and commercial communities in education, government, and industry. Within the last three decades, the advent of personal computers, advances in networking, and the availability of the Internet have made computing more widely available than ever.

In his second edition of *A History of Modern Computing* [29], Paul Ceruzzi provides a comprehensive look at this “dominant view” of computing history from 1945 to 2001. His chronological step through the timeline showcases major themes of computer systems technology availability through overlapping time periods, starting from “The Advent of Commercial Computing” and ending at “Internet Time”. His social-constructionist approach takes into account the fact that technical excellence of design does not ensure a system will be adopted for use. Most systems emerge for prevalent use through a variety of social and political influences as well.

In this review, we present an alternate history of computing. Visionary Computing can be followed with a parallel six-decade timeline (1945-2005) to the traditional view of modern computing history. The focus here will be on the ideas by forward-thinking scientists who spent most of their career envisioning the future of what computers can *really* do for us. As we will see, these innovative ideas might have been fanciful and outlandish for the time, and perhaps to this day have not come to full realization. However, it is because of such visionary ideas that the majority of our modern society enjoys the comforts of where we sit on the computing history timeline today. In addition, the groundbreaking visions of the first fifty years (1945-1995) have encouraged and influenced many scientists in more recent history to embark on their own journeys of visionary computing. The last decade (1995-2005) has seen the emergence of numerous new computing paradigms.

There is no doubt the history of visionary computing will continue to expand as we move forward into the future. New computing paradigms will continue to emerge until computing is seamlessly integrated into the fabric of our everyday lives and available to everyone in our (American) society. To support the goal of "seamless" integration, advances in human-computer interaction technology to develop novel interaction devices will be required. According to John Leggett, who coined the term Display Computers: "At this time, (good) models of interaction with DCs do not exist. Touch screen or pen-based interactions would be the most straightforward to apply, but both have drawbacks and are not appropriate for many applications. Gestural interaction may be the most natural, but the hardware requirements and cost of sensing and video equipment may be too prohibitive. Simple, single function (or few function), handheld devices that are wireless networked computers themselves may provide the best solution, but these must be designed and tested from scratch because they do not exist today and our standard interaction architectures would not correctly support such devices if they did exist." [117] To that end, we will briefly review literature of the history of human-computer interaction technology, emphasizing the last decade of research (1994-2004).

The perspective of visionary computing history does not minimize the importance of past and present technological developments. It is, in fact, counting on current advancements to support the realization of the new computing paradigms being introduced now and in the future. In the last decade (1995-2005), research and development in the areas of display technology, computing technology, and mobile technology, including wireless networking and human-powered computing have been innovative and even astonishing to the most seasoned computer professionals. In addition, improved manufacturing processes will make the necessary or desired (computer) components easier and cheaper to produce, in turn making them more easily available and affordable to the research community first, and commercially to the general public later.

Finally, following new computing paradigms and new and innovative technological advancements, new paradigms of use naturally follow. Our focus of computing for everyday people leads us to focus on the past decade (1995-2005) of applications and architectures to support computing for families, computing in everyday environments, computing and art, and interactive storytelling engines.

2.1 New Computing Paradigms

Students of Computer Science may or may not be familiar with the following names: Vannevar Bush, J.C.R. Licklider, Douglas Engelbart, Alan Kay, and Mark Weiser. The first half-century of Visionary Computing, 1945-1995, is well-represented by the personal visions of these five individuals who worked, and some of whom continue to work today, towards their "ideal" computing of the future. The cliff-notes™ version of the first five decades can be found in the following works of literature: the introduction of the "memex" in *The Atlantic Monthly* by Vannevar Bush [25] in July 1945; "man-computer symbiosis" by J.C.R. Licklider [118] in March 1960; "augmenting human intellect" by Doug Engelbart [48] in October 1962; the Dynabook by Alan Kay and Adele Goldberg [103] in March 1977; and the seminal paper by Mark Weiser [218] published in *Scientific American* in September 1991, introducing the concept of ubiquitous or invisible computing into our mainstream vocabulary. In addition, chapters 7, 9, and 11 of Howard Rheingold's book entitled *Tools for Thought* [161] discuss the contributions of Licklider, Engelbart, and Kay, respectively. The last decade, 1995-2005, has seen the emergence of many variations on the ubiquitous computing paradigm, as well as other new computing paradigms, illustrating the fact that visionary computing ideas will continue for some time to come.

2.1.1 Memex

In his July 1945 *The Atlantic Monthly* article titled “As We May Think”, Vannevar Bush [25] introduced his idea of the “memex”. This first event on the timeline of Visionary Computing was purely ahead of its time. Concerned at the end of the war that the collaborative efforts which had been driving science and technology to new heights would inevitably come to an end, Bush described in striking details his ideas and the future supporting technology in which the great, common “record of ideas” could be extended, manipulated and extracted by man thus ensuring “knowledge evolves and endures throughout the life of a race rather than that of an individual”. His goal was to provide a way for man to be able to “make real use of the record” and not “become lost in the mass of the inconsequential.”

A walnut-sized forehead camera was the first of his many noteworthy projections of the future. Wearing such an instrument, a scientist could easily record everything of interest, by photographing items “worthy of the record”, with instant viewing and later review capabilities. Bush introduced the memex as follows: “Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and, to coin one at random, ‘memex’ will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.”

Bush went on to give a detailed physical description of the memex device and the ways contents could be inserted, indexed, and viewed. The notion of “trails” was introduced as the main feature of the memex. The ability to specify distinct items to be associated with another to form new trails, and be recalled at will at any time in the future was a truly novel idea at the time. In one example, he writes about the possibility of needing to recall a previous trail some years later regarding “ways in which a people resist innovations". Trails could be reproduced and shared by inserting them into another individual's memex.

Bush's ideas were a vision of the future, but purposely tamed to reflect the technology available at the time. Any desire to envision the future in a no-holds barred fashion without any regard to known "methods and elements" was contained due to the fact that "prophecy based on extension of the known has substance, while prophecy founded on the unknown is only a doubly involved guess". Thus he concluded that his idea of the memex was "conventional, except for the projection forward of present-day mechanisms and gadgetry". That being the said, he also stated that some machines of the future might be "sufficiently bizarre to suit the most fastidious connoisseur of the present artifacts of civilization".

2.1.2 Man-Computer Symbiosis

Fifteen years after Bush's article appeared in *The Atlantic Monthly*, J.C.R. Licklider introduced his concept of a symbiosis resulting in the closest cooperation of the interaction of man with computers imaginable [118]. In March 1960, Licklider stated his vision thusly, "the hope is that, in not too many years, human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today". He predicted it might take five years to develop his concept. However, the results would be felt for many years thereafter, resulting in the most astounding creative and intellectual work possible, thus proving to be the most "exciting in the history of mankind".

The idea of man-computer symbiosis came to Licklider after he realized 85% of the time he spent on technical problems was not in the actual solving of them, but was devoted to the preparation required to get into the position of solving them. He categorized these time-consuming, preparatory tasks as mechanical and clerical, and did not think these processes to be the most efficient use of his time. Why not work in close cooperation with the computer and allow it to perform this routine, but necessary work for him? For his part, man would perform tasks the computer could not, resulting in a "cooperative interaction" to "greatly improve the thinking process".

Licklider details the human traits of man that would predispose him to handle specific responsibilities in a symbiotic relationship with the computer, as well as discussing the companion tasks more suited and thus designated for execution by the computer. Because his visionary computer did not exist, Licklider closes his presentation with the necessary advancements in technology that must occur to bring his idea of man-computer symbiosis into full realization. The prerequisites include providing for: time-sharing systems, computer hardware memory, memory organization and associated information storage and retrieval requirements, programming languages and the need for reusable procedures, and input/output equipment. The last category he described as the least advanced. It included the need for supporting free-form input-output interaction with the computer as well as with a co-worker, uses of wall displays for cooperative information sharing, and the merits of speech recognition and production.

2.1.3 Augmenting Human Intellect

In October 1962, a report published at the Stanford Research Institute by Doug Engelbart [48] presented his conceptual framework on augmenting human intellect. He defined his concept in detail as follows. "By 'augmenting human intellect' we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to his problems. Increased capability in this respect is taken to mean a mixture of the following: more-rapid comprehension, better comprehension, the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, speedier solutions, better solutions, and the possibility of finding solutions to problems that before seemed insoluble… We refer to a way of life in an integrated domain where hunches, cut-and-try intangibles, and the human 'feel for a situation' usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids".

The purpose of the report was to explicitly outline a "system approach to human intellectual effectiveness", such that a research program to guide the development of "artifacts" toward such an endeavor could be organized. His basic premise was that if technology could provide even the smallest potential improvement in the capability of a human's system to process information, the user could channel his efforts into incorporating more complex procedures, resulting in more enlightened, effective and productive problem solving and work methods. Research in the area would also serve to accelerate the natural, but often slow, evolutionary process of integrating such emerging technology towards everyday use and encouraging its widespread adoption and acceptance. In addition, the framework and prototype demonstration would perhaps set the stage and pave the way to further "radical equipment innovations…the digital computer as a tool for the personal use of the individual".

Engelbart describes his report as in the same category of Bush [25] and Licklider [118] before him: only presenting "speculations and possibilities", on "the possibilities of using a computer in real-time working association with a human to improve his working effectiveness". To that end, he provides a section of examples and discussion to further describe his concept of augmenting human intellect in less formal terms. He states, "each of the examples will show a facet of how the little steps that the human can take with his sensory-mental-motor apparatus can be organized cooperatively with the capabilities of artifacts to accomplish significant things in the way of achieving comprehension and solving problems… much of the structuring that goes on in the human's total problem solving activity is for the purpose of building a mental structure which in a way 'puts the human up where he can see what is going on and point the direction to move next'". Engelbart presents a detailed scenario of a demonstration that could occur several years later, through the fictional character “Joe”. Joe discusses and shows off computer-augmented functionality through personal conversation with the reader. Engelbart notes that while he expects the conceptual framework to hold up to future retrospect, it is likely the details such as those presented in the scenario might turn out differently.

2.1.4 Dynabook

In March 1977, Alan Kay and Adele Goldberg published work on their idea of personal dynamic media [103] ongoing at Xerox PARC. They referred to their vision as the Dynabook, and described it as “the size of a notebook which could be owned by everyone and could have the power to handle virtually all of its owner’s information-related needs” [103]. The computers used in the subsequent descriptions of their ongoing work were dubbed “interim” dynabooks. At the time of this article, their idea of personal general-purpose computing was “radically different” [139] than the time-sharing and batch systems of the day. They specifically stated their goals of providing the dynabook as a tool for “creative thought” and their goal of designing for a mostly neglected user group: children. Children as users required a different perspective of computing with unconventional requirements, compared to that of traditional engineering or business applications: interactivity, flexibility, and exciting visual displays, to keep their attention focused and interests up.

Kay and Goldberg described their implementation of the interim dynabook and presented various systems developed using their “new medium for communication”: the Smalltalk programming language. They talked about storage capabilities, drawing, painting, displaying high quality text in different fonts, and introduced the idea of multiple windows. They stated the “central notion” was simulation, and presented various systems programmed by users of varying ages in a wide breadth of applications such as animation, drawing and painting, music, business, and engineering. In their conclusion, they pose and answer their own question. “What would happen in a world in which everyone had a Dynabook? If such a machine were designed in a way that *any* owner could mold and channel its power to his own needs, then a new kind of medium would have been created: a metamedium, whose content would be a wide range of already-existing and not-yet-invented media" [103].

It is interesting to note, while much of the ideas of the Dynabook described by the authors in this paper (and another paper authored by Kay that appeared in *Scientific American* [104] on personal computers in September 1977) have come to be realized [139], Kay himself does not believe that the Dynabook vision has become a reality [21]. In a recent interview conducted in May 2003, he explains why. His main interest has always been children. The computer is a tool. Education is the key. Providing a rich environment to provide the optimal learning conditions for children to learn is the objective. The computer is a tool for such an environment and can "amplify" the learning process by enabling kids to access different "ideas, points of view, ways of thinking" [21], and should not be used just for presentation of accepted facts. It also has the capability to make learning fun, like playing.

Kay, himself, states it best: "play is the most important means of learning, and so you want to harness it for as many years as you possibly can. Play is nature's built-in mechanism for the child's deepest learning. And if the environment isn't rich enough, you lose the element of play. But if you make the environment rich and keep the play going, then you win in a big way. Because maybe the biggest question about education is, 'What is this kid going to do when teachers and parents are *not* around?' If children love the learning process, they want to spend all their time at it." [21]. The interviewer sums up the answer to the original question in this way: "why isn't the Dynabook a reality – what's missing is that the population to use them isn't there yet. We haven't taught people how to use them" [21].

2.1.5 Tools for Thought

In 1983, Howard Rheingold [161] first published his book titled *Tools for Thought: The History and Future of Mind-Expanding Technology*. According to the author, he "focuses on the ideas of a few of the people who have been instrumental in creating yesterday's, today's, and tomorrow's human-computer technology". He categorizes this influential set of people into three groups, starting with the "patriarchs" who provided the foundations during the "prehistory of computation"; continuing with the "pioneers", which included visionaries J.C.R. Licklider, Doug Engelbart and Alan Kay; followed by a newer generation with their own ideas he called "infonauts". The prevailing theme is that our use of technology is not limited by the hardware we invent, but rather it is the limit of our human minds that can potentially keep us from fulfilling our ultimate goals. We are limited only by our own imagination.

Rheingold's historical timeline starts in the early 19th century with Charles Babbage, the father of the Analytical Engine and Ada Lovelace, commonly known as the first programmer. He moves through history in chronological order detailing the personalities, lives and places of the people who were brilliantly inventing theories and technologies ahead of their own time, and their motivations and reasons for pursuing these paths. In many cases, the implications of their breakthrough inventions were not immediately recognized or known.

Possibly even more interesting is the author's second edition of the book, published in 2000. The author looks back on his past predictions and reflects on what came to be and what did not, in the preface. In addition, he revisits several people from the original book in 1999, including Doug Engelbart and Alan Kay, and includes excerpts of their interviews about their thoughts of post-1983 predictions and the innovations that came to be (user interfaces and the world wide web), in the afterword section of the book.

2.1.6 Ubiquitous Computing

Mark Weiser's seminal article introducing the concept of ubiquitous computing appeared in the September 1991 issue of *Scientific American* [218, 219]. A researcher at Xerox PARC, Weiser outlined his vision of the new technology, forecasting its emergence as the "dominant mode of computer access over the next 20 years". He used the terms "invisible computing", "embodied virtuality", and "ubiquitous computing" interchangeably to describe how we can reach our goal of "achieving the real potential of information technology".

2.1.6.1 Invisible Computing

The main idea of invisible computing [218, 219] was that hundreds of computers of all sizes would be embedded in the environment seamlessly and available to us at a glance when needed. They would be so invisible, well integrated, connected and interacting with one another that we would not know or need to know they are around, and thus "cease to be aware" of them. Weiser explains, "only when things disappear in this way are we freed to use them without thinking and so to focus beyond them on new goals". "People will simply use them unconsciously to accomplish everyday tasks."

The two features of ubiquitous computers are (1) the fact that they are location-aware of their surroundings and can potentially act accordingly, and (2) that they come in different sizes. Weiser introduces three sizes of surfaces for writing or display: inch-scale, foot-scale, and yard-scale called tabs, pads, and boards. He gives various examples of each and their uses, citing example prototypes developed at Xerox PARC. He then outlines in some detail the three major technological requirements of ubiquitous computers: cheap, light, thin, lower power displays and computers; software to support ubiquitous applications; and networking requirements to connect the hardware and software. The latter two were cited as the most problematic to solve.

After a narrative scenario of what it would be like to live in a world of ubiquitous computers through a character named "Sal", Weiser briefly talks about the social issues introduced by ubiquitous computing. He cites a sociological advantage: people and communities can be brought back together when technology no longer (literally) stands in the way. Fewer computer addicts, greater access to computing by all societies, and less chance of suffering from information overload are other advantages.

Mark Weiser continued working in the area of Ubiquitous Computing with the group he started at Xerox PARC in 1988 until his untimely death in 1999 [211]. In July 1993 he reiterated the fundamental aspects of the concept, illustrating by example and by a tutorial-style discussion the wide range and variety of computer science issues that need to be solved to make "ubicomp" a reality in our lives and our world [217]. This process includes building many prototypes of various shapes and sizes. Such research is necessary to prove the resulting ubicomp infrastructure can be viable, scalable, and will stand up to daily use. The key to the concept is that each ubiquitous computer is integrated into the environment and remains "effectively invisible" in the course of everyday activities, thus "allowing people to just go about their lives".

In this *Communications of the ACM* article, Weiser also describes how the original idea of ubiquitous computing came to be. His premise was: to fully and most effectively take advantage of computer technology, we should embody it into the objects we use on a daily basis in our lives. Particularly useful, would be to embed computers into those objects that play a role in communicating symbolic information. Since objects come in all shapes and sizes, in varying qualities, they should be so affordable as to be accessible to every member of society, and thus "bring computing to everyone".

In this and a subsequent article within the same year, Weiser details the work of ubiquitous computing that was ongoing in his group at PARC, and around the world [222]. The framework for ubiquitous computing includes all areas of computer science.

Hardware, networking, interaction devices, ubiquitous computing applications, social issues including privacy, and theoretical computation methods compose the breadth of the research challenges facing those working in the area. At the time of publication (1993), most work concentrated on solving the wireless networking issues required for the ubicomp mobile infrastructure.

Working on technical issues did not prevent Weiser from continuing to spread the word about the ubiquitous computing paradigm. In a January 1994 article [221], he published an essay on what type of metaphor could be used to describe the future of computing -- ubiquitous computing, in particular. Working through examples of previous metaphors commonly used for describing interaction with computers, he concluded a new metaphor was needed which emphasized the invisibility aspect of the impending future technology, such that the computer is not the center of attention. Weiser stated, "I propose childhood: playful, a building of foundations, constant learning, a bit mysterious and quickly forgotten by adults. Our computers should be like our childhood: an invisible foundation that is quickly forgotten but always with us, and effortlessly used throughout our lives."

2.1.6.2 Calm Technology

Towards the end of 1995, Weiser along with co-author John Seely Brown at Xerox PARC, introduced the concept of calm technology as possibly being "the most important design problem of the twenty-first century" [223]. Their succinct definition of a calm technology was one that "will move easily from the periphery of our attention, to the center, and back". The main goal is to design technologies which are encalming and do not require us to fully attend to them explicitly until we choose to do so. By placing various details within our peripheral reach, our knowledge can increase without the cost of information overload. A feeling of "locatedness" results from our ability to "know" what is happening around us in our environment. The authors give three examples of existing calm technology including: inner office windows, Natalie Jerimijenko's Dangling String, and Internet Multicast.

Within the next year, a second article authored by the duo at Xerox PARC included almost the same definition and examples of calm technology as [223], but included a different introduction, linking it to Ubiquitous Computing (UC). In "The Coming Age of Calm Technology" [224], Weiser and Brown partitioned the prior fifty years of computing trends to include two phases: mainframes and personal computers. The rising popularity of the Internet was deemed to be a transition phase between personal computing to distributed computing, and leading directly towards phase III, the ubiquitous computing era. In this article, they predicted the "cross-over point with personal computing will be around 2005-2020. The 'UC' era will have lots of computers sharing each of us."

The advent of the Internet (information sources) and the increasingly frequent examples of microprocessors embedded into everyday objects (information delivery systems) are two prerequisites of UC technology. It is when the information sources and delivery systems are networked together that a whole new environment to support invisible computing becomes available. Aside from the seminal group at Xerox PARC, there are many other researchers and companies working toward the UC era. They must investigate how prior technologies can be reconstituted into new contexts and revisit old systems design issues. Weiser and Brown reiterate their prior claim that the biggest challenge the UC era brings is "a focus on calm. If computers are everywhere they better stay out of the way, and that means designing them so that the people being shared by the computers remain serene and in control". They stated calm technology should remain the focus of design for the next fifty years of computing.

In early 1998, an article by Weiser appeared in *Communications of the ACM* relating Ubiquitous Computing to the university campus environment [220]. Here he talked about the three waves of computing technology revolutions, and how the university campus is always at the forefront and is thus naturally suited for the UC era. Wireless computing and the Web were cited as key factors of ubiquitous computing. Weiser gives numerous examples of UC in the form of credit cards, to be used as maps, schedules, campus dining services, and class information management systems. These would enable students and faculty to experience a calmer campus environment and educational experience: “our main focus can be the schoolwork or the person in front of us, while the computer almost imperceptibly aids our work”.

In March 1999, Weiser suddenly became ill and lived for only another month. As a tribute to his colleague and friend, Roy Want of Xerox PARC wrote an article published in February 2000 [211]. At the beginning of the article, a previously unpublished abstract to an article Weiser was planning to write before his death was included. The one paragraph abstract showed Weiser’s continued focus on his vision of ubiquitous computing, the focus of calm technology, and the realization of these concepts into our everyday lives. Through further research on pervasive connectivity infrastructures, his original idea of invisible computing and the calmness it would bring to us in a new UC era of computing would become a reality.

Want called Weiser a visionary and stated that his work at Xerox PARC on UC was invariably limited to the technologies available in the 1990’s. He predicted with further advances in computer technology, the ideas of Weiser would start to “take hold” and “be instantiated” as we move further into the 21st century. This is evident in the plethora of ubiquitous computing inspired and related research that has been published since Weiser’s death.

The end of 1999 and the year 2000 was a good time for everyone involved in computing research to stop and take stock of the past and look ahead to the future of the new millennium in their respective areas of work. This was no different in the field first envisioned by Mark Weiser in 1991. This time period was marked by several publications reviewing the past decade and the forthcoming challenges of UC research, in special issues [81, 80], history and surveys of the young field [225, 1], and related ideas [198]. Most authors have chosen in their research to emphasize one or several aspects of the ubiquitous computing paradigm and thus have coined new labels for their specific approach: pervasive computing, everyday computing, proactive computing, and everywhere computing; to name a few. However, some authors intend to use their terminology interchangeably with the original "ubiquitous computing" term as initially coined by Weiser. This is the case in the special issue of the *IBM Systems Journal* published at the end of 1999 on pervasive computing [6, 81].

In the introductory article to this special issue, Ark [6] states the purpose is to recognize the dawn of the pervasive computing revolution in direct relation to the HCI community. With one exception, the focus is on innovative and "provocative possibilities" the state-of-the-art research in the area is leading to. We will look at three papers from this issue [234, 50, 189] in following sections of this literature review. The fourth paper: the one exception mentioned above, was written by Weiser and published posthumously (with coauthors Gold and Brown of Xerox PARC) [225] about the beginning history of the ubiquitous computing research efforts, dating to 1988, three years prior to the publication of his seminal article in 1991 [218, 219]. Along with providing historical details, Weiser also provides commentary noting how ubiquitous computing has become a distinct field in Computer Science, incorporating the work and ideas of many areas previously thought to be distinct disciplines within CS. He closes his essay with questions and challenges that still remain. As illustrated in the following sample of UC research literature published after Weiser's death, many are following his lead.

2.1.6.3 Everyday Computing

In March 2000, Abowd and Mynatt of the Georgia Institute of Technology published a survey of the history of Ubiquitous Computing research from an interaction-based point of view, and presented issues still to be met in the applications research area [1]. Their motivation was to inspire current and future HCI researchers to tackle these challenges they characterize as everyday computing, and further the work Mark Weiser inspired only a decade earlier.

Everyday computing refers to a continuous, 24/7 availability of ubiquitous computing applications to “support informal and structured activities typical of much of our everyday lives”. Five common features need to be addressed among such everyday activities: (1) on-going, with no clear start or finish state; (2) continuous, mostly in the background, to be restarted from any state when desired; (3) concurrent occurrence of activities which may require multiple levels of awareness and notification; (4) time, or relative time, as an important source of information; and (5) the support of associative information models. Everyday computing tools should support and reflect context changes and seamlessly follow the user when he is physically shifting from environment to environment as is natural in our increasingly mobile society.

The authors list four HCI challenges they are specifically working on. In addition, they present a framework for evaluating prototype UC systems. Their premise is that UC research will be more palatable by the HCI community only after proper evaluation procedures have been conducted. However, they concede that because UC work mostly involves innovative and cutting edge research, this is often a difficult task to perform. Finally, Abowd and Mynatt briefly describe the social issues all areas of UC need to take into consideration. Privacy issues, access issues, invisibility issues, and consent issues, are but a few. Their conclusion: “our understanding of the social implications of these technologies will often come after people invent new, unforeseen, uses of these technologies”.

2.1.6.3.1 Context-Aware Computing

In addition to defining everyday computing, Abowd and Mynatt [1] briefly discuss prior work demonstrating two types of context in ubiquitous computing: position (location) as context, and identity (object recognition) as context. However, they posit that ubiquitous context-aware systems should also incorporate other contextual elements, such as time, history, other people and/or other information in the environment. The minimal set can be described when answering who, what, where, when, and why questions about the current context. However, the realization in an actual system will most likely require context fusion. That is, gathering contextual information from multiple sources and seamlessly supporting transition between context service areas as necessary.

2.1.6.3.2 Automated Capture and Access

The authors [1] also discuss the advantages and disadvantages of using ubiquitous computing applications to help people more efficiently record the events of their lives, and past work in the area. In everyday environments like the classroom or at work, or for personal events relating to friends, family or relatives, the two phases include: capture and later access. These are treated as separate research issues.

The introduction of specialized capture hardware may move the capture research area along. This first phase includes capturing raw information that can be played back for later review. However, if additional information units could be automatically derived from the original stream, it would help in promoting understanding of the captured events. In the second phase of access, serial playback is the easiest to provide. More difficult for applications might be to provide: automated summaries, foreshadowing of events in the captured stream that may be useful for determining quick access points, and ways to annotate or revise the original material while keeping track of the different versions.

In April 2005, the Georgia Institute of Technology reported the results of a study of "how users naturally conceptualize ubiquitous capture and access applications" [203]. The goal was to inform design models that move away from device-centered to user-centered applications users can create on their own.

2.1.6.4 Proactive Computing

In May 2000, an article in the *Communications of the ACM* by David Tennenhouse [198], a former director of the DARPA Information Technology Office, introduced the notion of proactive computing. Describing UC as a matrix along two dimensions: manual vs. autonomous systems and office vs. field environments, he placed proactive computing in the quadrant described as autonomous systems, field environment. In effect, proactive computing describes the pervasive placement of sensors and actuators in, and networked with, the physical environment; and characterized by previously unheard of computation speeds. No longer will humans be required to interact with proactive computing devices, instead they will merely supervise them, if that is necessary at all.

Proactive computing is tagged to replace interactive computing. When the sheer number of computers outnumbers the population in the world by factors of 100:1 or 1000:1, new ways of increasing our productivity and our quality of life must be investigated observes Tennenhouse. With the advent of the Internet and the ever-increasing numbers of embedded computers into everyday objects, traditional human-computer interaction should be and will be replaced by the proactive computer-environment interaction.

The author presents many scenarios of how to achieve proactive computing. This directly involves revisiting traditional computer science assumptions and questions we have relied on for the past 40 years since Licklider introduced his concept of human-computer symbiosis. Also of concern are the safety issues, social implications and ethics that arise due to the inherent invasive and pervasive nature of proactive computing technology. As a final conclusion, the author suggests students studying computer science be exposed to subjects in their academic curriculum that will enable them to solve the very physical and virtual world boundary issues required to support proactive computing in the future.

2.1.6.5 Everywhere Computing

In 2000, a second double issue of the *IBM Systems Journal* based on the MIT Media Laboratory included as one of three "themes" of the lab, a section on everywhere computing [80]. The first double issue highlighting work at the lab was published four years earlier in 1996 [79] and contained two articles we will look at shortly [233, 191]. Everywhere computing refers to the notion that more and more previously inanimate objects are being embedded with networked communication technology. This allows objects to react and adapt to the needs of the people who use them, and thus may improve their usefulness and efficiency factors [149, 60]. We will discuss two papers [155, 205] from this special section later. As an aside, the first two articles of the issue [138, 73] are more relevant to the visionary computing theme than the ubiquitous computing theme of this section. They illustrate how the director and the culture of the MIT Media Lab support and promote the philosophy and provide a working and educational environment conducive to training a new generation of visionaries to continue the historical timeline of visionary computing into the future.

In the first article [138], authored by the director of the lab, Negroponte discusses the major changes in thinking that have occurred during the past decade. Innovations in the form of "wild ideas" are not as quickly dismissed as before. While this "Media Lab style of thought" is much more widely accepted than before, he cautions extra care must be taken to ensure follow-up and substantiation of the innovative ideas once they have been realized. In the second article [73], Haase discusses the unique aspects of the Media Lab which has made it successful in its almost twenty year history. He acknowledges the students who do the work as the foremost "product" of the lab. They must be passionate about their work, and in doing so, when they leave the lab they are equipped to make significant contributions to change the world as they so desire. They will have already proven their ability to "build whole artifacts… the point of the exercise is as much the synthesis and integrity of the whole as it is the quality of the components."

In the two years following the Y2K milestone in computing history, research in the area of ubiquitous computing has flourished. Especially evident in 2002, was the increasing emphasis of computers to become aware and intelligent members of the user's environment. Another continuing emphasis was the "invisible in use" aspect of UC. Designing to minimize adverse environmental impacts was a newer challenge brought to the discussion forefront. In addition, two special issues, published by different research communities, show the work on Mark Weiser's 1991 vision has continued and will continue well past the first decade since its introduction.

2.1.6.6 Aware Information

In July 2001, Scholtz of the Defense Advanced Research Projects Agency (DARPA) introduced the notion of aware information [174], not aware information computing. While computing will be necessary to render the information, the key emphasis is that information the user would like to become aware of, is instantly and invisibly granted. Like Weiser's original vision of ubiquitous computing, location or context is important. Aware information systems would know when and where particular information delivery is desired without the user explicitly asking for it. In addition, aware information would augment features of objects, perhaps resulting in new form factors for traditional objects. Two examples she gives are using foldable displays as maps and self-loading digital ink content for books.

Scholtz emphasizes the need for interdisciplinary collaboration and identifies the following four areas of ubiquitous computing research: implicit interaction, task-based interaction, nomadic information management, and adaptable software architecture. She also discusses the fact that ongoing research and development of the underlying technologies are a necessary piece of the puzzle. Scholtz gives example scenarios of the challenges and surveys five projects at various university campuses working towards aware information. The creation of test beds integrating the four areas will be a necessary step to perform evaluation of the research. Additionally, she surveys ongoing ubiquitous computing research efforts around the world. In summary, she states "the vision of 'aware information' places more responsibility on computer systems for configuring themselves, monitoring themselves, maintaining themselves, locating information and determining if and when to deliver this information to users".

2.1.6.7 Unremarkable Computing

In April 2002, Tolmie et al. [202] from Xerox Research in Europe presented a paper on unremarkable computing. Their research focuses on the "invisible in use" aspect of Weiser's original vision of ubiquitous computing. They chose the home environment over the more-often used office environment, citing a new point of view would uncover a new perspective and result in new challenges for UC research. One of the authors participated in the households of five families as an ethnographer recording events as a member and not purely as an observer. It was quickly noted how routines dominated life at home and that the agenda was set to observe the "everyday phenomena of life".

According to the authors, unremarkable computing is not about making the computer physically or perceptually invisible. They posit that the way to achieve invisibility in use is to use embedded computation only as a means to "augment action". Much caution must be taken so as not to explicitly or implicitly disturb or interrupt the unremarkable routines they are to support. That is, unremarkable routines will no longer be unremarkable in nature if users need to take time out to describe what they are doing while they are doing it.

2.1.6.8 Sentient Computing

In May 2002, sentient computing [119] was described as an approach to ubiquitous computing that embeds computers into the environment and equips them with enough sensors to be able to perceive and predict what services their users will need at any given moment. Devices are embedded throughout the environment and are able to dynamically detect location and identification of objects, as well as features of the physical environment such as temperature and sound level. This information coupled with previously acquired repository information is used by the sentient system to model the current state of the user's environment and react appropriately to it. The authors describe the implementation of their sensor system called TRIP (Target Recognition using Image Processing) and present four context-aware applications developed with the system.

2.1.6.9 Pervasive Computing

In August 2002, a special issue on pervasive computing was published in *Mobile Networks and Applications* [116]. The editors use the term pervasive instead of the interchangeable term ubiquitous, because of its definition: "having the power to spread throughout". In a pervasive computing environment, users interact with pervasive computers that may be small "companion" devices (such as PDAs), or otherwise are embedded and invisible in the environment or smart spaces, and equipped with sensors and wireless communication technology. The devices, networked together, are aware of each other and their environment and thus able to provide services to the users in a seamless, unobtrusive manner. Six papers representative of current research efforts and the breadth of the fundamental and future challenges of pervasive computing appear in this issue. We will review one [142] in a later section of this review.

2.1.6.10 Green Computing

In September 2002, Jain and Wullert present the concept of green computing [100]. The authors contend that while research progresses towards Weiser's original vision, one additional concern that needs to be dealt with is the ultimate impact that resulting pervasive computers will have on our environment. When widespread realization of pervasive computing occurs, it will be too late to start thinking about what to do with the potentially large number of products that we no longer have any use for. In this article, the authors state the necessity to deal with the "garbage" and other environmental issues during the ongoing research and development phase of pervasive computers. New architectures and computer science issues must be considered from the outset to minimize future waste products and lower energy (power) requirements. This must occur throughout the design and manufacturing process. Maximizing the lifetime of future pervasive computing devices can be accomplished through software, or reuse and recycling of hardware components. The authors present a scenario in which all phases of a cell phone's device lifetime has been carefully considered in a green pervasive computing context.

2.1.6.11 Mobile Computing

In December 2002, a special issue on ubiquitous computing was published in the *Communications of the ACM* [120]. In the introductory article, Lyytinen and Yoo [121] predict the paradigm will "come of age" within the next five years to a decade. The new focus will be on how to integrate work in mobile computing and pervasive computing into the realization of ubiquitous computing paradigm. While the three terms are often used interchangeably, they present three distinct definitions. Mobile computing is characterized by computing devices and services that physically move with us when we move about our environment. Examples are lightweight devices we carry in our pockets or wear in our clothing or on our body. However, in pervasive computing, computers dynamically obtain information from the environment, and thus are able to react or provide services in an intelligent manner. Pervasive computers may include those embedded into the environment with sensors, or personal badges we can carry with us.

Merging the two areas of research will bring ubiquitous computing to full realization. "In its ultimate form, ubiquitous computing means any computing device, while moving with us, can build incrementally dynamic models of its various environments and configure its services accordingly. Furthermore, the devices will be able to either 'remember' past environments they operated in, thus helping us to work when we reenter, or proactively build up services in new environments whenever we enter them" [121]. Thus, the two dimensions of ubiquitous computing are: a high level of mobility and a high level of embeddedness. Mobile computing boasts the first trait, but not the second; while pervasive computing research has demonstrated the high level of embeddedness without a high level of mobility. The final quadrant in the 2x2 matrix, would be traditional business computing: with low mobility and low embeddedness.

The issues and challenges addressed in the six remaining papers in this edition, is a good indicator of the state of research in Ubiquitous Computing that has been ongoing in the past couple of years. Topics can be loosely divided into the following areas, including: mobility [40, 188, 157], business [54], social [70, 101], software infrastructure [10, 158] and "environmental" issues [44, 171]. Lyytinen and Yoo sum up the current state of ubiquitous computing research with the following observation. "Researchers in this field are still 'dreaming' and 'creating problems' as much as they are solving problems and recording and theorizing about effects. Researchers need to find ways to maintain rigor of scientific research without restraining their ability to imagine." [121]

2.1.6.12 Intimate (Ubiquitous) Computing

A workshop held at an international conference on Ubiquitous Computing in October 2003 introduced a new variant of ubiquitous computing, called "intimate computing" [204]. In their workshop proposal paper, Bell et al. [13] cite the origin of this concept linking intimacy and ubiquitous computing, as the September 1991 issue *of Scientific American*. In this publication, Mark Weiser's seminal paper on ubiquitous computing appeared directly before an article authored by visionary Alan Kay, who talked about "intimate, notebook-size computers" (the Dynabook).

The authors discuss the three ways intimacy and technology are related: (1) technology "knows" of and responds to the user's "intentions, actions and feelings"; (2) users "wear" technology, or it resides in the body (in the form of networked nanobots); and (3) technology “helps” the user express their “intentions, actions and feelings” toward other people. The purpose of their workshop was to “deploy the notion of intimate computing as a way of exploring the relationship of people to ubiquitous computing”. The workshop included focusing on four specific “perspectives”: how daily life affects use and understanding of computers, how cultural differences affect intimacy, the relationship between play and intimacy, and the need to design computers such that they are more intimate (vs. impersonal).

In April 2005, Kaye et al. [105] studied five couples separated by long-distance and concluded “meaningful interaction” could be accomplished through “minimal communication” (via exchanges of one-bit messages).

Since Weiser’s first publication on ubiquitous computing in 1991, there have been quite a few other researchers who have shared their visions of new computing paradigms. In 1991, David Gelernter published a book describing the future software revolution in his concept of “Mirror Worlds” [59]. Andre Meyer described his vision of “The Worldwide Real Virtuality” in 1995 after reviewing the concept, history, and state-of-the-art of pen computing [130]. In 1996, Steve Mann described his latest working prototype of the “WearCam”, his research endeavor in the area of wearable computing [125, 216]. In 1997, Ishii and Ullmer published their initial work on “Tangible Bits” at the MIT Media Laboratory [97]. Spohrer [189] described his vision of the “WorldBoard” in 1999. In 2002, Ben Shneiderman introduced his “New Computing” paradigm in the book titled *Leonardo’s Laptop* [184]. Most recently, in May 2003, DARPA published a call for proposals to implement a “LifeLog” system to capture a user’s every activity, every hour of every day, 24/7 [37] -- much more information than what was envisioned in the 1945 memex [25]. As mentioned before, some of these novel ideas have remained simply visions, while some have been realized in ongoing research projects. These ideas are briefly described below.

2.1.7 Mirror Worlds

In 1991, the Oxford University Press published a book called *Mirror Worlds* [59]. It describes David Gelernter's vision of users turning on their computer to view the real world as it is happening right outside their window, so to speak. Inside the computer is a giant software information machine which runs 24-hours a day, providing different perspectives of information that is publicly available for all who wish to view it. Using various tools, the user is able to get a sense of the whole picture of the Mirror World he is looking at, as well as delve deeper if he wishes. Thus, Mirror Worlds are "software models" of the real cities and real places we live and work in. Building Mirror Worlds will cause a software revolution that will result in "public software works" or "civil software-engineering". The information is made available to anyone who wishes to access it, and users are provided with the means to understand the big picture: the deep picture, the live picture, the history, the experience, and most importantly, the basic idea. Gelernter states, "Sure, you might be too tired this evening to turn the box on. Or you might have better things to do. Or you might be such a bored and apathetic goofball that you *never* turn it on, never even peek inside a Mirror World. Doesn't matter. The fact that *this box exists*, that the world is *right there* on your coffee table, makes all the difference."

2.1.8 Pen Computing

In July 1995, a comprehensive look at pen computing was published by Andre Meyer in *ACM SIGCHI Bulletin* [130] starting from the history of writing, to the state-of-the-art in pen computing systems available at the time of publication. The author described the vision of pen computing as fulfilling our "human way of communicating thoughts and ideas". Using freeform handwriting as input to the computer would greatly increase their ease-of-use, and users would be free to concentrate on the content of their desired input. All that is required is the pen and a flat surface that can record and display the user's input from the pen. Meyer discusses the hardware technology required, handwriting recognition issues, and mobility support required in the form of wireless communication technology. He then discusses how pen computing differs from traditional computing in terms of user interfaces, new programming paradigms, and new form factors.

In the final section, Meyer presents his vision, which he calls "The Worldwide Real Virtuality". Real virtuality is based on the notion of a virtual space or Information Space we can build for ourselves from a vast Information Warehouse of integrated multimedia available at different locations. The interactive paper metaphor describes the interaction platform of mobile pen computing: it will be "as easy to use as paper". Data will be available to the user from any source for the asking. All one will need to do is connect to it using a personal device. "The key effect of all the advances in different technological fields will come into play when they are all together seamlessly integrated in a coherent and transparent way. Then, the user will not need to know any details of different technologies, but will understand them and make use of them immediately" [130].

2.1.9 Wearable Computing

According to Falk and Bjork, the wearable computing paradigm seeks to move computers into clothing, such that they "function as an extension of our body and mind" [53]. This enables the wearable computer to become a truly personal computing device to the individual wearing it. This is the intention of Mann [125], who has worn his WearCam throughout the years he has spent refining it. Advances in technology are enabling the wearable computer to become smaller and smaller in size and embedded as invisible devices into our clothing. Users could use energy they produce themselves as the source to power these small devices they are wearing, as suggested by Starner [191]. (See the New Technology: Research & Development section on Human-enabled Technology below.) While wearable computing and ubiquitous computing are two separate paradigms [53], Stemberger [88] believes wearable devices to be the "final piece of the puzzle" to enable seamless, invisible computing of the future.

In November 1996, Mann presented a paper proposing 'Smart Clothing' [125] at the ACM Multimedia conference. Past prototypes date back to1980 and have continued to evolve through research and advancements in available technology. (See Mann's website for updated prototypes [216].) The ubiquitous computing concept of smart spaces is limited to those environments especially equipped to be "smart" and give control of the environment to another individual or organization, thus bringing up serious privacy questions linked to surveillance issues. The author prefers a more personal technology under his own control. The WearCam was designed for "day-to-day living within the surrounding social fabric of the individual" [125] who owns and wears it (most) all of the time.

The personal computing system consists of the wearable computer and personal imaging system (one or more wearable video cameras) connected wirelessly to the Internet, always in the "ready" mode when being worn. The original purpose of the apparatus was to assist the user during lapses of visual amnesia (who is that person, or how do I get there) or to augment the user's visual perception (for example, an artist becoming aware of light vs. shade in the scene). Other uses include the ability to share visual memory and maps of the environment with others, and taking notes complete with illustrations using visual images. Mann conducted a variety of experiments outside the lab (MIT Media Laboratory), some with more than one user at a time, and presented the results. Also included, is a discussion on the possible uses of 'smart underwear' to control room temperature or to keep personal medical records.

In January 2002, an article by Stemberger [88] on wearable wireless devices provides a brief future scenario on how one's "digital persona" might be of assistance in our everyday lives, in providing information we need for our impending decision points, or in the automatic execution of tasks deemed to be necessary. He takes a broad look at the current status and what place wearable computing will play in the future. Stemberger defines wearable computers as apparently invisible, portable miniature devices that transparently allow users to interact with their environment in the performance of computerized tasks. The key is the user may also be simultaneously engaged in performing other everyday tasks at the same time. He discusses the need for industry to combine research efforts in four major areas: smart spaces, input/output mechanisms, invisibility, and widespread acceptance. Among the challenges are hardware, software, energy demands, and usability. He concludes the biggest challenge to widespread adoption may be privacy and security issues.

2.1.10 Tangible Bits

In 1997, complementary to the work of wearable computing in shifting the focus of computing away from the desktop to the physical body, was the new concept of tangible bits, which focuses on merging computing with the physical environment. Ishii and Ullmer, from the MIT Media Laboratory, introduced the concept of tangible bits [97], in which people benefit from haptic interaction with common objects and peripheral awareness of background cues in their surrounding environment. In the first case, by associating digital bits with physical objects, they can be grasped and manipulated by the users. In the second case, by associating specific information with various ambient media (light, shadow, or water flow) commonly available in the background, peripheral senses can be employed by the user in determining if and when attention needs be shifted towards it. The key is the ability of the user to monitor the peripheral information in the background, without needlessly distracting them from their primary task at hand in the foreground.

The authors present their prototypes of interactive spaces and everyday objects that offer tangible user interfaces and the use of ambient media. Finally, they discuss their use of the optical metaphor they used to solve design problems they encountered in the course of their work. In their conclusion, they mention the abacus as a historical physical computational device that might be a good model for the future. In their follow-up work published in 2000 [205] formalizing their conception of tangible user interfaces, Ullmer and Ishii begin where they left off in 1997: with the abacus. It is an example of a physical artifact that has no distinction between input and output [199]. The beads on the abacus serve as representations of numerical information in their physical arrangement, while simultaneously serving as the physical controls with which to manipulate the numerical information. This example of "seamless integration" is what makes tangible bits different from traditional desktop computing graphical user interfaces.

2.1.11 WorldBoard

Towards the end of 1999, Spohrer introduced the concept of WorldBoard [189]. Spohrer began his article with the following questions. "What if we could put information in places? More precisely, what if we could associate relevant information with a place and perceive the information as if it were really there? WorldBoard is a vision of doing just that on a planetary scale and as a natural part of everyday life". Spohrer's vision is an example of augmented reality. Specific, meaningful information is superimposed exactly where a person would like to view it most: that is, where he currently is, "in real time and in real space". Or alternatively, he may wish to view the information from where he is through special display glasses. The information must first be posted to a virtual bulletin board or poster-like "place" on the planet, a location defined by a six-faced one-meter cube. The place it is posted should be its most likely, natural location, so people seeking the information can easily find it to retrieve it. Retrieving it could be accomplished manually, or automatically with location-aware devices. Such mobile devices would serve as a view or a "porthole" into the place. Manual retrieval would allow for viewing through superimposition or glasses as previously mentioned. One of the three primary design goals was "to be so simple and useful that people use it in everyday life".

Spohrer discusses in detail the initial WorldBoard concept, historical background into viewing and display technologies, possible implementation plans and issues, and lists potential applications of information in places. He states his idea as being one not unlike many that came before him: Bush [25], Gelernter [59], and Weiser [218, 219] -- a "technology forecast…examples of predictions of fundamental changes in our relationships to information and technology". Visionary projections into the future are based on current and emerging technologies. It is possible that advancements occur beyond what was predicted, enabling better results than originally forecasted. On the other hand, the author concedes his "dream" may be viewed as "an oddity, a technological 'side show', that never quite worked right or had enough utility". There are many social issues that could hamper adoption efforts such that a concept is not embraced, despite a demonstration that it could be realized in the technological sense. Spohrer discusses these issues, as well as why his idea may not be as farfetched as it might initially sound.

2.1.12 New Computing

In October 2002, Ben Shneiderman of the University of Maryland published a book titled *Leonardo's Laptop: Human Needs and the New Computing Technologies* [184]. Portions of the book are available on the Internet [183, 182, 185]. He describes the central theme of his book in the opening paragraph. "The old computing was about what computers could do; the new computing is about what users can do. Successful technologies are those that are in harmony with users' needs. They must support relationships and activities that enrich the users' experiences." [182] The challenge is to design technology to more closely match the "needs of humanity". Achieving the goal of new computing will require a deeper understanding of what the user wants, all the while encouraging more people to become "users". The end result of design should be realized in innovative products users need that are useful in function and at the same time create satisfaction in use. The author describes his vision of new computing as being inspired by Leonardo da Vinci and his lifetime of "ambitious visions". Leonardo was "an innovator who was far ahead of the available technology". Thus, Shneiderman's book on his new computing vision is shaped by the question, "if Leonardo were alive today, how would he use a laptop and what kind of novel computers would he design?"

2.1.13 LifeLog

Most recently, in May 2003, the Defense Advanced Research Projects Agency Information Processing Technology Office (DARPA IPTO) put out a call for proposals to implement a prototype system for their concept of LifeLog [37]. The system would capture all aspects of a LifeLog user's 24-hour day, basically functioning as "a powerful automated multimedia diary and scrapbook". The stated purpose by the IPTO for funding the development of this unprecedented type of technology is to bring to realization their vision of a "new class of truly 'cognitive' systems that can reason in a variety of ways, using substantial amounts of appropriately represented knowledge; can learn from experiences so that their performance improves as they accumulate knowledge and experience; can explain their actions and can accept direction; can be aware of their own behavior and reflect on their own capabilities; and can respond in a robust manner to surprises".

Recording of the user's life is accomplished through capturing every aspect of the physical experience as they are living it -- anytime, anywhere, and all the time. Thus, the input to the LifeLog system will consist of a wide variety of various sensor data, all interactions the user may have with any person or computing technology, plus all contextual, environmental and cultural information that the user comes in contact with. The LifeLog system in turn would be able to develop threads and timelines of the user's life and basically be able to tell about his life and identify his personal "preferences, plans, goals, … routines, relationships, and habits".

2.1.14 Summary

As we have seen, there have been a wide variety of visionary ideas in the last six decades of computing. Some have come to fruition, while some have not. Some are still in the works after decades, while some are just starting to take shape (to be attempted). In a sense, we seem to have come full circle. From the concept of the "memex", where Bush's vision was to enable individuals to store and retrieve records pertinent to his life on a single personal device, to the concept of "LifeLog", where individual lives are recorded and evaluated in an automated fashion to make "accessible the flow of one person's experience in and interactions with the world in order to support a broad spectrum of associates/assistants and other system capabilities" [37].

In the following section, we take a brief look at how human-computer interaction technology has helped make past visions a reality. We also take a brief look at the history and the last decade of research in the area. It is these current trends in research that hopefully will provide the interaction technology to support future visions of computing. Or perhaps, after surveying the current offerings, we will see the human-computer interaction technology available today may not be totally adequate. If this is the case, the research community will be served notice that new and innovative interaction techniques still need to be developed to support the envisioned computing that will be available in the near future.

2.1.15 Human-Computer Interaction Technology

In 1988, the Association for Computing Machinery Special Interest Group on Computer-Human Interaction (ACM SIGCHI) put together a committee to develop a set of recommended education guidelines for university-level undergraduate courses and curriculum on the subject. The initial report was published in 1992. The authors were members of the Curriculum Development Group and are well known in the field of HCI. In 1996, the report was placed on the web, and is updated periodically; the last update dated December 2002 [77]. Among the stated goals of the report: to be used as a self-assessment guide, a resource guide, a rationale document, and to encourage professionals, both academic and non-academic, to continue their education in the field. The committee states this as the best way to keep up with a field that has in the past, and will continue to be, rapidly changing as a result of ongoing research coupled with advancements in available and upcoming technology.

The main purpose of the report was to offer guidelines on content and courses that would provide interested students the necessary HCI foundation to take with them after graduation. In chapter 2, they provide the following definition and describe the two separate components: the computer side (HCI technology) and the human side. "Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." Although they emphasize the computer science aspect, they stress the interdisciplinary nature of the field and how important it is to keep the context of each problem in the proper perspective.

They provide a brief history of HCI in the report, including the work of Licklider [118], Engelbart [48], and Kay [104], as one line of research providing "a number of important building blocks for human-computer interaction". In addition, they list future trends of computing and characterize how the field of HCI may enable or be affected by predicted advancements in hardware technology, new and innovative techniques, and embedded computation in the environment. They close the chapter with a detailed list of topics which is an "inventory of the current state… what is known that is worth teaching" in the field of HCI and discuss the relationship with other disciplines as needed.

An email addressed to the HCI community solicited views on the state of HCI design based on a 40 year time frame: the past 20 years, present day, and the future of the next 20 years. Excerpts of many of the 40 responses were published in early 2000 [45].

Many of the respondents are well known in the HCI field. The responses covered a variety of topics in HCI. The editors organized them into four categories: foundations, interactions, domains, and design practice. More specifically, the interactions section included the topics of: hardware devices, technology, access, interaction styles and cultural issues.

One excerpt from one respondent follows. "The whole chain from the small interface to use situations to services themselves must be analyzed and designed. The demand for that will be huge, and nobody knows yet how it is to be done. Some challenge indeed – it will take the design of interfaces into a new millennium, both literally and figuratively." The final comment in the article was by Aaron Marcus. He speaks of a legacy for those who follow. "We have no choice as humane beings but to grasp hold of our surfing boards, ride the waves, enjoy the show, hoping for the best and planning for the worst. May the next generation inherit a world of improved global understanding made possible by superior global communication systems with excellent, thoughtful, sensitive HCI design."

In April 2005, Jonathan Grudin, an active member of the SIGCHI community, published an article about the process of getting research published in the computer science discipline (in the United States); and more specifically, how it has affected the HCI academic community [71].

2.1.15.1 History of HCI Technology

Myers published "A Brief History of Human-Computer Interaction Technology" [133] in 1998. The HCI technologies are divided into four groups: basic interactions, application areas, upcoming technology, and software tools and architectures. For each area, he gives a definition and emphasizes the time, person and place of its first conception. He shows how subsequent significant research proceeded to first popularize it within university and corporate circles and then closes by noting when and by which commercial product it eventually became available to the public. His goal was to illustrate, through example after example, how many of the innovative ideas originated from the university research community first, and only after many, many years of research are they proven to be ready for use in a widespread manner. In effect, today's research results in tomorrow's interfaces. Myers states that academic funding for university research is a necessity to ensure a steady flow of doctoral-level graduates who can carry on the current research, or teach HCI courses to future generation of computer science students. In his view, computer science is the necessary link between HCI research and the eventual availability of the resulting technology through commercial products.

2.1.15.2 Starfire Video

Following the introduction to HCI and the brief history by Myers, the focus on the remaining section of the literature review was to be on the last decade of research into HCI, 1995-2005. However, we would be remiss if we did not mention the SunSoft video prototyping project detailing their proposed "next-generation interface". Unveiled in 1994 [200], the goal of the film was to tell a story and illustrate the vision of the Starfire project's "advanced integrated computing-communication interface" set in time at one decade later. One of the reasons for choosing video as a user interface prototyping tool was that they could present the overall idea of the look and feel of the novel interactions they were proposing without being limited to actual technology available. This enabled the designers the freedom to be creative and envision with only one restriction: the interface should be grounded such that it could be implemented in hardware and software technology available by the year 2004, as illustrated in the setting of the film.

The paper presents observations and guidelines the designers wanted to follow to avoid the pitfall of "straying into fantasy" and how they handled each situation in a case study of the video prototyping project. Among the novel user interface elements presented in the film were: a very large curved desktop display surface also used as an input device via gesture, stylus, mouse, and voice; a display in the form of a clipboard; and portrayal of quick, intelligent access to the user's information space and context of the environment from a distance. In addition, they added elements of unexpected events that may occur in real life. For example, the issue of privacy is raised when the main character of the film inadvertently is able to view a marriage proposal of a coworker. The author concludes, "we found by adhering to the guidelines we developed, we were able to produce a drama with a strong story line, a large number of clear and definite messages, and a sprinkling of controversial elements, all wrapped in a video prototype that still demonstrated the fundamentals of an implementable new architecture".

2.1.15.3 Tangible User Interfaces

The idea of tangible bits was first introduced in 1997 [97]. Here we look at two examples, mediaBlocks and musicBottles from the MIT Media Laboratory. In 2001, Ishii et al. gave the following concise definition of tangible user interfaces. "Tangible user interfaces give physical form to digital information, and exploit the human senses of touch and kinesthesia. Their goal is to take advantage of the richness of multimodal human senses and skills developed through a lifetime of interaction with the physical world" [98]. Through tangible bits, Ishii is striving for "seamless interfaces between humans, digital information, and the physical environment" [96]. In April 2003, work at University of California, Berkeley and Ricoh Innovations showcased the use of archival paper artifacts as a tangible user interface [111].

2.1.15.3.1 mediaBlocks

In July 1998, continuing work at the MIT Media Laboratory on new interaction techniques resulted in mediaBlocks, an example of tangible user interfaces [206]. mediaBlocks are physical icons made of wooden blocks, also known as "phicons". Each block is issued an identification tag, and becomes the physical interface representing the online media (file paths, URLs, etc.) it embodies. mediaBlocks function as user interfaces in three capacities: as the transport mechanism analogous to traditional GUI "copy and paste" from media source to media display; as the gateway for seamless transfer of online media content between two computers and other media sources or displays; and as physical interfaces to navigating their content through special physical browsers and sequencers. Ullmer et al. describe the user interface and implementation issues, as well as system design issues that led to the prototype form of mediaBlocks presented in this paper.

2.1.15.3.2 musicBottles

Another example of tangible user interfaces is musicBottles, presented by Ishii et al. in March 2001 [98]. In this project, bottles were used as the embodiment of digital information, and also served as the physical controls for the same information. Multiple bottles were placed in an aesthetically pleasing installation with color lights and a stage. The manipulation of the each bottle would result in a different sound and a different display of the lights. The result was an aesthetically pleasing, musical composition with a corresponding dynamic-changing display of lights. Informal observations and feedback from users showed the minimal bottle interface was intuitive to most without any explanation. It appealed to the users' emotions and many made repeat visits to the installation, bringing friends in the process.

2.1.15.3.3 Books with Voices

In April 2003, Klemmer et al. described the joint effort at UC Berkeley and Ricoh Innovations called "Books with Voices" [111]. Their prototype used barcodes to augment paper transcripts, thus providing a tangible, paper-based user interface to access digital videos from which the transcripts originated. The video clips included audio output and were displayed on the user's PDA. The evaluation of the prototype showed the interface to be "calm", allowing users to stay on their task of active reading. More importantly, it augmented the reading task with an "audiovisual experience" not available with traditional paper transcripts. It also augmented the editing process, providing quick, random access to desired segments that proved to be a big time-saver compared to the access of traditional analog tapes. The authors concluded their paper with the following observation. "Reading is a highly evolved practice. Our evaluation showed that Books with Voices effectively enables active reading by scaffolding new technologies on paper, which is highly familiar, cheap, and usable."

In 2004, published research on tangible user interfaces included a study of "tangible usability" [85], a high-level tangible user interface description language and software toolkit [179], taxonomy for analyzing tangible user interfaces [55], heuristics for "spatial" tangible user interfaces [180], a tangible user interface using "virtual tangible widgets" [201], and designing tangible user interfaces specifically for children [196, 160].

2.1.15.4 Information Appliances

According to Norman in his book titled *The Invisible Computer*, published in 1998 [143], the term "information appliances" was coined by Jeff Raskin in 1978. Norman presents a case that computers have become so complicated for so many people, it is time to start afresh, with a brand new paradigm of computing. Simple devices called "information appliances" will perform a simple set of specialized functions that are easy to learn and use. Simplicity and reduced complexity are the key goals. While information appliances are designed for distinct tasks, they should also be able to share and communicate with other appliances as one component of a system. Norman states, "as long as there is free and easy interchange of information among appliances, and especially if reconciliation of data can be made automatic, there is no penalty for owning a variety of appliances that cover the same activities. The user chooses the one preferred for the circumstances and when the activity is complete, the information is effortlessly distributed and shared among all". The computing and infrastructure technology behind the information appliances should and will be invisible to the user.

2.1.15.4.1 Universal Information Appliance

In 1999, Eustice et al. [50] presented their work at IBM to develop a universal information appliance (UIA). Their research vision was to "create an environment in which a single device can serve as a person's portal into the digital and electronic domain". The device could be the user's PDA or a wearable computer. The domain would be any application, information store, or electronic device, i.e. the "entire electronic universe" the user comes into contact with in the course of his daily life. The authors describe a detailed scenario in which the UIA is of assistance 24 hours a day, directly (through dynamically varying interfaces), or indirectly (processing occurring in the background), according to the user's personal profile, current behavior, and immediate environmental context.

The prototype implementation of the UIA can be categorized as occurring on three fronts: UIA device requirements (input, output, data storage, and network communication); communication infrastructure (software or middleware to support connection between the UIA and servers providing information, interfaces, or applications); and wireless communication (enabling the devices and infrastructure to communicate). The biggest challenge, however, is in the seamless integration of the UIA into the public as a "ready assistant". Planned improvements to the initial prototype include adding support for a speech interface and providing other "novel" input and output interaction mechanisms. The ultimate goal would enable the user to choose from a variety of UIA devices, and provide the flexibility for the user to switch to another UIA device as the current situation changes, without any loss of functionality from device to device in the process.

2.1.15.4.2 Embodied User Interfaces

In a September 2000 *Communications of the ACM* article, Fishkin et al. [56] described a new interaction paradigm particularly suited for information appliances they call "embodied user interfaces". By placing various physical sensors on the body of an information appliance and with the required computation materials within the body casing, the device itself can be used as the user interface for natural and direct manipulation. According to the authors, the domain for embodied user interfaces are "common electronic tasks for which a strongly analogous physical task already exists".

In this paper, they focus on paper-related tasks, discussing the design and implementation of three examples: page turning of books, perusing Rolodex cards, and annotating a document. Testing showed that a preliminary introduction to the new interaction paradigm and quick demonstration were sufficient to enable the users to explore the possible set of manipulations and feedback for each device. In addition, the authors are working to develop a framework for designing embodied user interfaces.

2.1.15.4.3 InfoPoint

Another example of a universal device was introduced by Kohtake et al. [113] in December 2001. The InfoPoint System is designed to provide a consistent, universal interface for performing information (data) transfer in a networked environment. Transfer can occur between traditional objects, such as computers and information appliances, in addition to non-traditional objects, also referred to as non-appliances (i.e. paper and other physical artifacts). Each real-world object is marked with a "visual marker" that can be recognized as a unique target by InfoPoint. A marker can be as simple as a printed label. InfoPoint provides a "get and put" operation analogous to the traditional desktop version of "drag and drop" to accomplish its transfer task. The components of the system architecture include a mobile hand-held unit, a wearable laptop PC, a shared database, the InfoPoint Manager, and all marked objects in the environment. They give example applications in which every user would have their own InfoPoint device to transfer data, operate appliances, retrieve data from marked papers, or augment papers with data. They plan to improve their system by adding proximity identification technology such that the system would be aware of the user's environment and respond according to the current situation.

2.1.15.5 Ubiquitous User Interfaces

The trend towards ubiquitous user interfaces requires new interaction technology that moves the user away from the traditional desktop graphical user interface into more non-traditional and novel user interfaces. Recently, there have been many researchers contemplating the future of user interfaces that satisfy the ubiquitous nature of computing in the near future. Here we report on natural, dissolving, and disappearing user interfaces.

2.1.15.5.1 Natural Interfaces

In their March 2000 survey of ubiquitous computing, Abowd and Mynatt [1] listed as one of three important challenges, the interaction theme of providing more natural interfaces to "facilitate a richer variety of communications capabilities between humans and computation". Handwriting, speech and gestures are natural ways people communicate with each other and are already being used in user interfaces. The authors recommend extending this concept to promote use of their underlying or "raw" data types (ink, audio, video, sensor data). Toolkits supporting fundamental primitive or combined operations would provide programmers the means to manipulate these data types as easily as traditional keyboard and mouse input. New forms of input are potentially new sources for errors. The authors discuss error handling for recognition-based tasks in the areas of error reduction (eliminate or reduce them in the first place), error discovery (make the user aware it has occurred), and error correction (provide toolkits with a reusable library of techniques).

2.1.15.5.2 Dissolving User Interfaces

In March 2001, Andries van Dam described his view of the future of user interfaces in the title of his *Communications of the ACM* article, as "disappearing, dissolving, and evolving" [210]. He cited the move away from human-computer interaction to human-human and human-computing environment interaction as an ongoing trend. Another trend is the realization of Weiser's ubiquitous computing vision through various form factors, for example, digital paper, reactive wall-sized displays, context-aware and general-purpose devices, and smart environments; as well as invisible computing embedded in our appliances, furniture, and clothing. Van Dam lists three specific user interface issues that still must be met: taking advantage of the human senses for input and output, solving the "one size does not fit all" problem such that interfaces take into account different needs by different users for different tasks, and development of design principles to accommodate both able-bodied and "differently-abled" users. In addition, he lists specific problems that need to be solved before these issues can be resolved, stressing the need for the interface to appear seamless and adapt to the user depending on his individual situation and needs. He concludes the key to moving away from the traditional desktop metaphor to a more natural style, is to base advances of interaction technology on our knowledge of the human user. Only then can we "leverage the great advantages we may expect in raw computation, storage, bandwidth, and device technology".

2.1.15.5.3 Disappearing User Interfaces

In April 2001, a workshop was held at SIGCHI on disappearing user interfaces. The introduction, authored by Dey et al. [41], discussed how "novel computation artifacts" may or may not be known to the user as a computer. They defined three ways interfaces could disappear from the artifacts. Truly invisible interfaces occur in the background. The computer and environment are totally integrated, such that the user may not know they are interacting with an actual computer. In transparent interfaces, the UI is visible, but to the user, it augments their body in such a way it may not be explicitly noted by the user. The final category is subordinated interfaces. Here, the functionality of the artifact is not the primary noteworthy aspect to the user. He may be more interested in the aesthetic or personal aspect, so the user interface becomes subordinate. The goal of the workshop was to explore ways to design for implicit (vs. explicit) human-computer interaction. Thus, input to the computer consists of information based on the user and his current situational context. The focus of the workshop included technical and social topics to be considered in the design and implementation of disappearing interfaces for single users and co-located users of multiple, distributed, and connected ubiquitous devices.

2.1.15.6 Camera-based Interaction

Camera-based interaction was first introduced in 1985 by Myron Krueger's work on VideoPlace [114, 51]. According to Fails and Olsen, Krueger set the stage which "established cameras as an interactive input medium and sparked an interest in user interfaces that function by watching what people do rather than requiring overt inputs by a user" [51]. The following represents recent work in the area of camera-based interaction at Brigham Young University and Carnegie Mellon University.

2.1.15.6.1 Laser Pointer Interaction

In April 2001, Olsen and Fails [144] at Brigham Young University, presented their work on interaction techniques using an inexpensive laser pointer to manipulate information on a large projected display. Such techniques are useful for environments that require a shared display of more than one user, such as in group meetings or service repair shops. The prototype consisted of a laptop, a projector, and a camera focused on the projected display surface to track the position of the laser pointer. Interaction is accomplished by pointing the laser pointer at a widget (text box, list box, etc.) on the display, using one of four cursor modes (tracking, scrolling, graffiti, and dwell). Manipulation occurs by moving the laser pointer over the desired option, or using a button on the laser pointer to turn it off, depending on the interaction desired. The authors present the system architecture and discuss the primary issues of implementation. Preliminary testing resulted in encouraging results when comparing the laser pointer interaction with other more traditional interaction methods.

One year later, in April 2002, Myers et al. at Carnegie Mellon University presented the results of their experimental studies of laser pointers [134]. Their premise was that separating the technology-related aspects and the human-related aspects would be valuable to inform future designs and result in improvements to the usability of the laser pointers for techniques that are quicker, more convenient, and prove to be more accurate for the user. In the first experiment, users were tested on various ways to hold a laser pointer. In the second experiment, object selection using the laser pointer was studied, including the authors' technique called "semantic snarfing". Here, the content of the large display is copied onto the user's individual, smaller display to enable more detailed work, and then can be copied back to the original display. The conclusion was that the combination of using the laser pointer to indicate the wide area of the display coupled with the fine-grained capability on the "snarfing device" would improve use of laser pointers in general. The authors will continue to research further types of interaction techniques that can occur across multiple devices.

2.1.15.6.2 Light Widgets

In January 2002, Fails and Olsen at Brigham Young University reported on their continued work with camera-based interaction [52]. However, this research emphasized interaction by the user that did not require them to carry a laser pointer device, or any physical device at all. Their stated goal was "to create a low-cost, versatile, adaptable and integrated ubiquitous system that can be used in any indoor space". To that end, unobtrusive cameras are used to observe the "light widgets" in the user's environment. When the user touches a button, linear or circular light widget, they can manipulate controls such as switches, numbers, dates and times. While user feedback on the light widget is not provided, feedback can be obtained from an external platform integrated with the system. The implementation of the prototype was described. One key design issue was to keep the required equipment (two USB cameras and a PC) costs low. They also discussed how they solved the privacy issue of pictures taken by the cameras. The functionality of the cameras was described as purely an interactive, optical gesture detector device, such that the only information leaving the camera was the selected light widget value. The authors conclude that their system is useful anywhere "any visible surface can be turned into an interactive widget triggered by skin-colored objects".

2.1.15.6.3 Crayons Project

Fails and Olsen also reported on camera-based interfaces in April 2003 [51]. The Crayons Project is not a device or an interaction technique, but rather a tool set to enable user interface designers to build camera-based interfaces. The goal is that programmers can design for their interaction task at hand, in a focused and relatively quick manner, without having to learn the details of image processing or machine learning. With the Crayons tool, the designer simply collects sample images and trains a "classifier" to recognize the specific set of pixels that are of interest. Once he has finished refining the classifier, it can be exported. The authors describe their implementation of the Crayons tool. The results of the user evaluation showed that their goal of providing a tool that would allow designers to build camera-based interfaces on the order of minutes, rather than months, had been reached.

2.1.15.7 Natural Interaction

Maes [123] defines natural interaction as "on-the-go" interaction that does not explicitly require any extra or special actions from the user. Aesthetic interaction [151] focuses on interaction as a means by which users can establish new relationships with the everyday materials with which they come in contact. Attentive user interfaces [82] is another example of natural interaction, as it requires no explicit effort from the user.

2.1.15.7.1 Aesthetic Interaction

In April 2004, Petersen [151] discussed how aesthetics is essential for designing remarkable, visible technology for the home. Aesthetics may refer to how something looks or is used, but more importantly, it should support exploration and "learning through use" by "triggering" the user's imagination. Peterson further states design focus should be on "how the means of interaction can be surprising, engaging, and serve to establish a new relationship to the materials people interact with" [150].

2.1.15.7.2 Attentive Interaction

Also in April 2004, Holman et al. [82] describe attentive user interfaces as those that "sense and process user attention". In their example of Attentive Art, the original presentation of art is "tuned" and evolves based on non-verbal cues of viewers. Here, previously "passive observers" turn into "subtle participants". The ability to track specific user interest is useful for managing large displays of information either through filtering or enhancement.

In July 2005, Maes [123] describes attentive objects as a way to " 'personalize' the interaction and present to a specific person the information that is of the greatest potential interest, given that person's focus, context, interests, and past actions". In natural everyday interaction with augmented everyday objects, users can be offered instant information that has immediate relevancy to where they are, what they are doing, and where their attention is focused. This information is presented on common objects the user already has access to, in a lightweight, non-invasive manner. Once aware of the information, the user may choose to attend to the information or ignore it.

2.2 New Technology: Research & Development

For those of us who have been using computers for well over a decade, the current trend in technological advances of the last ten years (1995-2005) have almost been as novel as the visionary computing ideas we discussed previously. Display, computing, and mobile technologies are continuing to be researched, refined, and developed in academia and industry today. The resulting technology will enable the realization, or may lead to further improvements in the current state of development, of many of these new computing paradigms in the near future. This, in turn will lead to improved paradigms of use for everyday people, which ultimately, is the whole point of having computing technology in our lives in the first place.

The areas of recent and emerging technology that are of interest include: human-enabled technology, advances in wireless networking, advances in display technologies, and novel and improved manufacturing paradigms to lower the cost of computing technologies of the near future. Human-enabled technologies include those that harness the actions or use the human body as a power source, in effect, enabling "human-powered" computing. Advances in wireless networking have resulted in the popularization and the widespread use of mobile computing devices, both in personal-area (up to 30 feet) and local-area environments (100-500 feet). These technologies, coupled with advances in display technologies and new manufacturing paradigms, will soon open new doors resulting in novel form factors and enabling personal computing for our society quite unlike the desktop experience offered by the traditional personal computers prevalent today.

2.2.1 Human-enabled Technology

Human-enabled technologies include those that harness the actions or use the human body as a power source. Advantages of "human-powered" computing include increased mobility for the user, who will no longer need to rely on outside sources of power. Even eliminating the need for batteries [191] can be beneficial; it promotes "green computing" [100] and can reduce the weight of a wearable computer. Another human-enabled technology, also introduced in 1996 at the MIT Media Laboratory, was the use of the human body to support personal area networks [233]. It was demonstrated that two people could exchange electronic business cards by a simple handshake, or in other words, by generating an external electrical field [90].

2.2.1.1 Human-powered Wearable Computing

In 1996, a MIT Media Laboratory student's research [191] in the area of wearable computing sought to determine if power required for a user's wearable computer could be generated by his own actions prior to or during the use of the computer. If the energy requirement for embedded computers in clothes or other form factors worn on the body could be solved in this way, batteries would no longer be needed. Starner starts with the basic definition of energy and power, and gives examples of typical sources of energy we use in our everyday life, and how they compare to the power requirements of traditional computers. He explains how to harness various human body functions such as body heat, breathing, blood pressure, and motion through: upper limb motion (playing the violin), walking, and finger motion (typing). The author concedes his ideas maybe "fanciful", but each may offer advantages not offered by other methods. Finally, he presents two scenarios of wearable computers (one his own) and their power requirements as scenarios.

2.2.1.2 Personal Area Networks

In 1996, Zimmerman introduced his research on personal area networks initiated at MIT Media Laboratory and continued at IBM [233]. This novel technology takes advantage of the human body's "natural electrical conductivity" to enable the sharing of information via the transmission or download of data. The prototype system described in the paper and demonstrated at IBM [90] illustrated the use of PAN to exchange business cards between two people. The sender's transmitter is continually transmitting data and is worn or placed close to the body. The recipient's receiver can also be worn, or is likewise placed close to his body. The moment the sender and recipient shake hands, the necessary external electrical field is generated to enable the transfer of ASCII business card information between them, through their bodies. In addition, personal area networks are designed to be useful in exchanging information between the myriad of personal information devices people commonly carry or wear with them. This enables the networking of personal devices without the requirement of wiring them together physically, thus providing tremendous ease of use. Example PAN devices are worn on the head, placed in shirt or pant pockets, or worn on the waist, and may include "commonly worn objects: watches, credit cards, eyeglasses, identification badges, belts, waist packs, and shoe inserts" [233]. The author also discusses a third area of PAN applications: to initiate and expedite everyday "consumer business transactions", such as automatic and personalized video rental checkout.

2.2.2 Wireless Networking

In 1999, Zimmerman extended his research into personal area networks to ponder the ubiquitous nature of personal devices [234] and the use of 2.4 GHz radio to enable wireless communication between them. Around the same time, the IEEE initiated a standards working group to investigate the issue [187]. By June 2002, the 802.15.1

standard had been published using Bluetooth as the specification [92]. Since then, short-range wireless networking is commonly known simply as "Bluetooth" [75]. Bluetooth technology has been predicted to "lead toward ubiquitous connectivity and truly connect everything to everything" [72]. A short rendition of the story that started in 1996 with personal area networks [233] and ending with the availability today of Bluetooth wireless technology follows, after a brief aside for a short definition and description of currently available wireless networking options.

"Wireless networks rely on technology that does not require physical connections or proprietary cables to transmit information from one point to another" [75], defines Hayes in his book published in 2003 on Wireless Computing. In his chapter on wireless networks, he discusses the issues to consider when considering which networking options can support particular applications. They are coverage, bandwidth, security, standards, and cost. Wireless network options include short-range infrared networks, short-range Bluetooth networks, medium-range wireless local area networks (WLANs), and wireless wide area networks (WANs). Infrared networks require devices to be in the line of sight, a fact that is not conducive to their mobility. Bluetooth networks provide short-range (up to 30 feet) mobile wireless connectivity between personal devices within a user's personal space. Wireless LANs provide a medium-range solution (100-500 feet) with superior data throughput (11 to 54 mbps) and can be used for wireless connection with a wired network, for example, buildings, universities and hospitals. Wireless WANs are purchased wireless services and include dedicated data networks, digital cellular networks, paging networks and satellite networks. The coverage is extensive, but they are traditionally used for voice instead of data services [75].

2.2.2.1 Wireless Personal Area Networks

In late 1999, Zimmerman followed up his introductory article on personal area networks with another, titled "Wireless networked digital devices: A new paradigm for computing and communication" [234]. His updated, concise definition: "Personal area networks connect mobile devices carried by users to other mobile and stationary devices. Their communicating range is scaled to the spatial interaction volume of humans (e.g. the reach of a hand or the audible distance of a voice), typically under ten meters." The author presents various wireless communication and networking issues of how wireless personal area network technology can be used to meet the increasing demands created by a "proliferation" of mobile computing, ubiquitous computing and wearable computing devices.

After comparing the performance values of the various communication channels (electric, magnetic, optical, electromagnetic) wireless PAN can use, the author concludes that wireless radio frequency (RF) may be best suited for it, specifically the 2.4 GHz (gigahertz) radio ISM (industrial scientific medical) band. (Note that the prototype of exchanging business cards from his previous research [233, 90] uses the electric field channel.) The commercially available IEEE 802.11 standard wireless LAN (WLAN) was not suitable for PAN due to power and range issues. However, at the time of publication, the IEEE wireless PAN (WPAN) group had recently been formed to modify the IEEE 802.11 WLAN standard to specifically address PAN application standards. Zimmerman discusses two other groups addressing 2.4 GHz radio wireless communication specifications that target two different environments. The first for the home: HomeRF Working Group, and the second, Bluetooth Special Interest Group, for business. After comparing the specifications, the author concluded the HomeRF to be more applicable towards the IEEE WPAN and thus more suitable for 2.4 GHz PAN radios. He stated in the ideal situation a single standard for both environments would provide "a continuity of connection" and would benefit both customers and manufacturers alike.

The wireless communication channel is only one of many networking issues. Depending on the wireless PAN application, data formats may vary. For example, HTML (HyperText Markup Language) and XML (Extensible Markup Language) are two ways web documents are used to specify the text and graphics displayed on the Web to be accessed by traditional computer users through their desktop machine. WML is another such language, specific to the Wireless Access Protocol (WAP). This protocol addresses small mobile computing devices such as cell phones. Users typically view simple text and graphics on the phone display and may select simple options. Zimmerman, however, envisions "wireless networked digital devices" to go beyond these traditional uses. Some wireless PAN devices may be used to "capture lecture notes off a 'smart' whiteboard, and receive a menu, place an order, and pay for a meal." Jini, JavaSpaces, and TSpaces are several "innovative research projects" which provide network discovery and delivery services. The author closes with a concise description of the ultimate goal. "A browser can point to any Web page on the Internet – a PAN device should be able to likewise 'plug in' to innumerable services anywhere in the world."

2.2.2.1.1 802.15.1 WPAN

A February 2000 article published in *IEEE Personal Communications* details the history and evolution of the IEEE 802.15 WPAN working group formed in March 1999 [187]. As a side note, this article appeared in a special issue whose subject was "Connectivity and Application Enablers for Ubiquitous Computing and Communications" [17]. This publication also contains the tribute to Mark Weiser by Roy Want [211], and the abstract to an article Weiser was planning to write for this issue titled "Pervasive Connectivity and Calm Technology". Thus the focus of the issue is to "showcase some of the technologies that could be used to enable and realize ubiquitous connectivity" [18]. The editors describe the relationship between standards and the realization of ubiquitous computing envisioned by Weiser. "Standardization enables ubiquity, since it allows many manufacturers to develop interoperable devices. This allows the economies of scale to kick in and the market forces to work, which ultimately allows consumers to buy these devices and corresponding solutions worry-free." [18]

As Zimmerman noted in his late 1999 paper, originally it was thought that the 802.11 WLAN [91] would be a good starting point and could be modified to bring about a new standard for WPANs. However, after the first year of study, the conclusion was that it was not. Specifically, a WLAN is used to wirelessly connect devices to "a traditional Ethernet wired LAN" to extend it, or possibly to replace it (thus doing without the wires altogether), in an office or conference room environment [187, 75]. Thus, the goal of this 1997 standard was to optimize "data throughput over distance and mobility". However, WPAN devices are the plethora of mobile, personal devices that travel with the user ("carried, worn, or located near the body") on a daily basis, wherever they need to go. The WPAN standard must meet worldwide requirements, such that the user would avoid breaking the law when traveling from country to country. Key criteria were "low cost, low power consumption and small form factor", "ad hoc connectivity with minimal operator intervention", and "coexistence in the 2.4 GHz band" [187].

The initial call for proposals by the working group for a WPAN draft standard was answered by only one group: the Bluetooth Special Interest Group, in July 1999. In September 2001, an article providing an update to the WPAN working group was published in [87]. It briefly describes the architecture and relationship to Bluetooth, includes a comparison to the WLAN standard, and discusses the four task groups working within the committee, each of which is focused on a different dimension of WPAN. Nearly three years later, the IEEE 802.15.1 Wireless Personal Area Network standard was published in June 2002. It is based on the Bluetooth v.1.1 Foundation Specifications [92]. The IEEE 802.15.1 Bluetooth WPAN standard, in turn, standardizes the Physical (PHY) and Medium Access Control (MAC) layers of Bluetooth [87].

2.2.2.1.2 Bluetooth

In the same February 2000 issue of *Personal Communications* was an article by Haartsen describing the Bluetooth radio system [72]. The Bluetooth Special Interest Group was formed in 1998 by a consortium of companies to create an industry-wide and thus worldwide standard to "enable electronic devices to communicate wirelessly via short-range ad hoc radio connections." The first version of the standard was published in July 1999, and was made available for commercial use, royalty-free and license-free.

The author cites the advantages of wireless connectivity: "eliminates the need for wires, cables, and the corresponding connectors… and paves the way for new and completely different devices and applications. The technology enables the design of low-power, small-sized, low-cost radios that can be embedded in existing (portable) devices. Eventually, these embedded radios will lead toward ubiquitous connectivity and truly connect everything to everything. Radio technology will allow this connectivity to occur without any explicit user interaction." The author provides an in depth look at the Bluetooth Radio System architecture, issues, and tradeoffs, and its design towards ad hoc connectivity (peer communications without coordination of any type).

The official Bluetooth website [20] contains up-to-date information on Bluetooth wireless technology. There is a brief description of how it works, a listing of products or "Bluetooth innovations", as well as an online SIG newsletter available for subscription. In 2002, Microsoft announced support for Bluetooth in Windows XP, while Apple Computer announced the same for Mac OS X [19]. Bluetooth and 802.11 WLANs both use the 2.4Ghz radio band, but provide different range capabilities (30 feet vs. 300 feet) and thus are complementary to each other. An example scenario is put forth by Hayes: "Bluetooth can provide a user with wireless links between mobile devices, computers, and peripherals, while a WLAN can offer continuous connectivity to enterprise data, applications, and the Internet." [75]

2.2.2.2 Wi-Fi, or Wireless Local Area Networks

Wireless local area networks use radio technology based on the IEEE 802.11 standard, more commonly known as Wi-Fi (short for wireless fidelity). Wi-Fi networks provide the freedom of wireless and mobile access to the Internet from almost anywhere, including increasingly available public "hotspots", perhaps at a local restaurant [173], the airport [209], or even a rural small town square [131]. Identifying hotspots in local communities or travel destinations can be a challenge. These may be (1) registered in a database at a specific website [227], to be accessed by the Internet or via WAP-enabled cell phones [228]; (2) identified by physical window stickers at the location of the access point; (3) common knowledge of specific business chains (for example, Starbucks) that offer Wi-Fi network access to customers; or (4) automatic detection of a local Wi-Fi signals by the mobile user's computer [208]. Note that many free hotspot access points do not provide extensive security, if any at all. For secure Internet access, a Virtual Private Network (VPN) is good option [226]. It is used on many university campuses.

2.2.2.3 Wireless Application Protocol

According to the WAP Forum website, the Wireless Application Protocol (WAP) is the "open, global de facto standard that allows mobile users of wireless hand-held devices to securely access and interact with Internet-based content, applications, and services." [215, 214] This "enabling technology" includes a wireless application environment (or WAP microbrowser) and set of WAP communication protocols based on standard Internet technology (such as IP and HTTP) [94, 213]. WAP version 1.0 was released in 1998. WAP 2.0 was ready for public review in August 2001 [215] and released in January 2002 [213]. Together, these two documents describe the latest WAP specification in some detail. An interesting feature is the ability of the WAP push technology to enable applications servers to send mobile device users personalized web content without requiring applications to poll the servers explicitly (which is not practical in terms of wireless communication environments). The WAP push complements the Internet pull model, where users explicitly request Web information through their browser [215, 213]. IBM Zurich Research Laboratory has implemented a Java implementation of WAP, dubbed WAPsody, to be used as their simulation, development and testing environment for WAP applications [89].

2.2.3 Display Technology

Organic light-emitting diode (OLED) displays may provide the "biggest breakthrough in visual display of words and pictures since invention of the television" a December 2002 report in *Forbes Magazine* proclaims [230]. This award-winning visual display innovation may bring the idea of wallpaper that can be unrolled on the living room wall to create a giant ultra-thin video screen to many homes in the near future [69]. In January 2003, it was described as a "potential disruptive technology that could replace both the cathode ray tube (CRT) and liquid crystal displays (LCD)" [193]. While LCD technology is still improving, it has some inherent limitations that open the door for new competition in the market of flat visual displays. Because they do not actually emit light, LCDs must be backlit to be seen in most lighting conditions, have a limited viewing angle, and require a long process of manufacturing steps to assemble which is costly [69, 193].

2.2.3.1 OLEDs

OLEDs are organic polymers that act as semi-conducting materials to function as individual picture elements or pixels. Also known as light-emitting polymers (LEPs) they generate light in similar fashion and may be patterned like their inorganic solid-state semiconductor counterpart, the LED (light-emitting diode) that is commonly used in dot-matrix-style message boards. On an OLED screen, electricity can be fed individually to each pixel converting it directly to light and resulting in no wasted energy. Another advantage of OLEDs is brightness: the OLED pixel emits more light than a corresponding LCD, given the same amount of electricity [230, 69, 137]. OLEDs are PPV (p-phenylene vinylene) polymers, each of which emit their own different color and may be made into visual displays using one of two methods. First, a thin film of PPV may be applied to a glass or plastic substrate; or secondly, the molecules may be mixed into a solution to be sprayed directly onto a screen, or a variety of durable, flexible and cheap surfaces such as cloth, paper, etc. [230, 137]. The process of depositing the organic molecules on substrates uses the same technology as current ink-jet printers, significantly lowering the cost of manufacturing with OLED technology, as long assembly steps are no longer required. The trend towards flexible displays using all-plastic circuits and transistors is moving closer to reality [69, 193].

Initial uses of OLED technology are as backlights for LCDs in notebooks [69], or as displays on handheld mobile phones and personal digital assistants (PDAs) [193]. Other non-traditional uses can also be imagined. “Philips Electronics NV predicts that eventually ‘light-emitting polymers will evolve to become as flexible as fabric and thin as paper. Formed or flat, applications in the domestic, mobile, office, and public environments will place 'spread' or 'task' lighting on ceilings, walls, floors, or free hanging’ …LEPs could be used for glowing walls and flexible TV screens that roll up” [137]. Others predict the capability of OLED screens having the ability to capture and store images they display, and play them back as well. More practical applications may include the use of OLEDs in airplane "luminescent ceiling panels" which would replace the currently used heavy lighting fixtures [69]. Using a cloth substrate, OLEDs can easily be built into clothing on which one can display a personal message on t-shirts. Universal Display Corporation has developed a prototype "roll-up Web browser" using a flexible screen and a pen as a carrying case [230]. The first prototype of a plastic television screen was developed in 1998 and described in [137] as being black and white, 2 mm thick, 50mm X 50 mm square, with an advantage of being viewable at all angles.

New displays utilizing OLED technology for computers and other consumer electronic products are starting to be manufactured and made available to select groups of customers and users, by companies such as Kodak and DuPont Displays. While the easiest application of the new OLED technology is simply to replace the current usage of CRTs and LCDs in traditional products to take advantage of the benefits of brighter displays, more vivid colors, better contrast, and higher resolution; there are many more innovative ways in which this new OLED technology should and will be used in the future, to change the way everyday people will interact with the computers and their living environment of the future. According to Physics professor Richard Friend of Cambridge University, who co-discovered that PPV would emit light over a decade ago: “OLED could open new areas of art or, more prosaically, lead to a new kind of camouflage bodysuits, even constantly updated newspapers that look and feel like the original thing. ‘One always falls into the trap of going into the straight-replacement mode,’ he says. ‘But with a revolutionary technology you should not simply map it on to existing products. Not if you are an optimist.’ ”[230]

An “International OLED Technology Roadmap” was published by the U.S. Display Consortium to “facilitate international effort” for the decade between 2001-2010 [11]. Bardsley describes the characteristics of OLED technologies and matches them to potential applications of consumer product markets. In addition, specific target parameters for OLED displays in terms of cost and performance are listed for three stages of development: (1) proof of principle by 2004; (2) cost and performance in line with competitive technologies by 2007; and (3) cost and performance exceeds such that OLED technology is the dominant over competitive technologies by 2010. The other application area of OLED technology the roadmap discusses is “large area OLEDs for use as diffuse light sources”.

In November 2004, the U.S. Display Consortium offered a different title, “The USDC Flexible Display Report” [12], also authored by Bardsley. In addition to OLEDs (under the emissive displays category), the report included electronic paper displays and backplanes [166], inkjet printing [27] (under the manufacturing processes category), and roll-to-roll processing [164].

In March 2005, CNN.com ranked OLEDs as number 17 on their list of top “ ‘25 non-medically related technological innovations that have become widely used since 1980, are readily recognizable by most Americans, have had a direct and perceptible impact on our everyday lives, and/or could dramatically affect our lives in the future.’ “ [33] (The Internet ranked first; personal computers, third; e-mail, fifth; portable computers, seventh.) On their website, Kodak Corporation has an offer to “most Americans” to design their own OLED displays. “The Kodak OLED Evaluation Kit AMEV1 includes everything but the video source for testing OLED applications in new or existing products" [112].

Universal Display Corporation maintains OLED technology may bring the following commercial products in the near future: "wrist-mounted, featherweight, rugged PDAs; wearable, form-fitting, electronic displays; roll-up, electronic, daily-refreshable newspapers; ultra-lightweight, wall-size television monitors; and office windows, walls and partitions that double as computer screens" [207].

2.2.4 Manufacturing Paradigms

Novel, improved, and more cost-efficient manufacturing methods will have a big impact on the timeline with which everyday people will have affordable access to the innovative technology being researched and developed today. According to one manufacturer, the access to revolutionary devices by the public is only one advantage: "the real story is how it will benefit the environment and improve the way that people create, design, conduct business, access information, communicate, interact, travel, write, read, learn, enjoy art and entertainment, and experience their world" [167].

2.2.4.1 Roll-to-roll Processing

Roll-to-roll processing is a novel production method of fabricating electronic components and devices in mass quantity on a roll made of flexible materials such as plastic substrates or metal foil. This results in "light, thin, rugged, and flexible" products that are "affordable, faster to prototype and faster to market". The process, also known as "web processing", is likened to newspaper printing. Instead of printing words, specific integrated circuit patterns are precisely printed on thin flexible rolls using lithography. This manufacturing paradigm is less expensive than traditional manufacturing methods of electronic devices, and is expected to "create an entirely new industry that will one day rival the current electronics industry in size, and surpass its impact on our lives…" Flexible OLED displays are one of many potential applications.

According to Rolltronics Corporation, the process will produce “devices that we can’t yet imagine” [165, 167, 164].

2.2.4.2 Electronic Embroidery

In 2000, Post et al. published their work at MIT Media Laboratory on the development of “computationally active textiles” towards creating “truly wearable” computing [155], integrating “embedded computation and sensing into everyday life to give users continuous access to the capabilities of personal computing.” The process dubbed e-broidery or electronic embroidery, is applicable to clothing, as well as textiles substrates found in furniture or other items of décor. The authors state the advantages of textile-based computing to include the durability, washability, conformability, and various aesthetic properties of textiles, and where applicable, the traditional properties associated with clothing as expressions of our personality, as protection from physical elements, or as a means to carry items around on our person as necessary. The first step of the e-broidery process produces the desired patterns of fabric circuitry with conductive thread or yarn. The fabric circuit is then integrated with the desired component packaging through a stitching or a weaving process. Finally, a multi-layer e-broidery process is employed to add the additionally required multiple layers of complexity to the circuitry as necessary. The authors present various example applications and discuss materials used in electronic textiles.

2.2.4.3 Flexonics

Flexonics [27] is a research effort led by John Canny at University of California, Berkeley. The stated goal is “to design fully-functional appliances and human-interfaces from organic materials, and to build them without assembly using 3D printing techniques” [26]. In January 2003, a *Scientific American* article declared flexonics as having “the potential to revolutionize industrial design. Rather than a casing housing the circuitry, the casing is the circuitry” [140]. In other words, this emerging new technology, also known as polymer mechatronics, enables a complete device, from the casing to the electronic circuitry will be printed together "in one go". Layer by layer all of the required components are printed on flexible substrates to build a 3D product using a 3D inkjet printer. The resulting device can then be made fully functional hot off the press by simply adding the required batteries. Because the devices will essentially be one piece, there are no components that can be replaced should they break. However, prototypes can be produced at lower cost with this method than traditional manufacturing methods. Another potential niche is for low-cost manufacturing of disposable products [140]. As of August 2003, a 3D printer had successfully been built for printing of "simple mechanisms" [162].

2.3 New Paradigms of Use

As mentioned before, new paradigms of use naturally follow new computing paradigms and new and innovative technological advancements. Our focus of computing for everyday people leads us to focus on the past decade (1995-2005) of applications and architectures to support computing for families, computing in everyday environments, computing and art, and interactive storytelling engines.

2.3.1 Computing for Families

Recently, there have been several presentations at the ACM CSCW and CHI conferences on the subject of capturing memories and relationships among families or groups of people. The following presents a sampling of applications that help to facilitate, manage, or communicate important historical events of a family, close relatives, or even a tight-knit group of co-workers. Traditionally "manual" metaphors and media such as scrapbooks, montages, portraits, and memory boxes are employed, which help to bridge the gap between the common "manual" applications and new computer-supported applications.

2.3.1.1 Scrapbook Metaphor

The FotoFile System [115] is an application developed by Hewlett Packard Laboratories that helps consumers organize and manage their digital media. The goal was to implement techniques to make it easier for people to annotate their photos and related audio and video recordings. Search tools were augmented with browsing and visualization techniques to work efficiently with possibly large-sized collections. Predefined metadata fields were used to define the common property of objects. The primary organization metaphor used was the photo album metaphor. The scrapbook metaphor was employed to build "photo scraplets". The sequential ordering of the events in the scraplets helps the user annotate their personal memory in a lightweight fashion. Automatic links are made when the same photos are used in multiple scraplets. Thus multiple stories can be displayed depending on which scraplets are chosen during playback of the photo album. The authors conclude that providing a system for consumers to organize their digital photography and video can "provide powerful and novel ways for people to express, preserve, and connect". In previous work utilizing the scrapbook metaphor at IBM [57], a video scrapbook of a scientist's thirty-five years on the job was created from twenty hours of professionally videotaped interviews with colleagues and friends. A touch screen provided the interface by which users could select interview segments that were designed to resemble "moving and talking pictures on pages of a scrapbook".

2.3.1.2 Digital Family Portraits

Digital Family Portraits [135] is a reciprocal set of displays depicting a lightweight qualitative visualization of how an elderly individual who is living at a geographic distance away from extended family members is doing. For those who choose to live in their home alone, there may be concerns for their safety and well-being, due to gradual physical and cognitive changes in their life that occur naturally as part of the on-going aging process. These concerns are partially alleviated when there is a way to unobtrusively check up on the individual from a remote location periodically. This simultaneously allows the individual to “age in place” while providing “peace of mind” for the responsible party living at a small or large distance away. A particular digital family portrait displays icons that represent an activity, health, or relationship category around the frame of the portrait of the elderly individual person to keep in contact with. The measurements are defined in four levels: from extreme low to extreme high. Larger icons show higher measurements. The awareness information displayed on each frame represents the last 28 days of the category in the resident's life. Each of the four weeks is represented on one side of the frame. The twenty-eight icons are displayed clockwise around the frame, with the icon in white representing the current day. The most recent days are highlighted by different gradients in background color. Trends are represented by dots around the periphery of the frame, while a crisis day is reflected by placement of the corresponding icon closer to the center of the frame.

2.3.1.3 Living Memory Box

The Living Memory Box is a project at the Georgia Institute of Technology to “support the collection, archiving and sharing of moments from a child's life” [192]. They conducted ethnographic-style interviews with a selected group of parents with children to determine what functionality a prototype framework would need to encompass. Their Artifact Path Model details the type of artifacts typically saved and the breakdowns parents encounter when trying to accomplish the task of saving memories when busy with other parts of their everyday life. The physical prototype is centered around the Living Memory box. Input to the centralized archive in the box is accomplished through an array of digital devices. The box also serves as a narration device, by which parents may annotate new objects with basic metadata or tell stories about artifacts as they are captured and saved in the box. The archived objects can be linked together. Once connected, similar objects can be accessed together during later retrieval. The goal of these researchers is to “collect…into one central spot and build connections between the virtual and physical artifacts” and “to develop a system that removes most of the work from current methods”.

2.3.1.4 Web Montage

Anderson and Horvitz named their system “Montage” [4]. They define a “web montage” as “an ensemble of links and content fused into a single view”. The system automatically creates personalized web portals by examining user's previous usage patterns on the web. To accomplish this task, web access logs for each user are collected and mined for candidate pages. Montage then builds a personalized model of browsing interests based on patterns of navigation of the user. Different montages are typically available: main montages group by topics, topic-specific montages display embedded pages and their related links, and finally a links-only montage. User evaluation showed that they preferred to have a way to manually adjust the content on their personal web portals after the automated system ran its course. The authors also discovered they should strive to limit the time to less than three seconds for the loading of the montage page.

2.3.1.5 Digital Group Histories

Shen et al. present ongoing research at Mitsubishi Electric Research Laboratories titled the “Personal Digital Historian” (PDH) project [181]. The purpose of the system is to “facilitate conversation and storytelling” about the collective past of a group of people belonging to the same family, organization, or institution. The ease with which digital materials such as photographs, videos, and text documents can be archived with the new technology today, creates collections of recordings that can capture the group history and culture of those who are illustrated in them. The PDH system can “help people to construct, organize, navigate, and share digital collections in an interactive, multi-person conversational setting”.

2.3.2 Ubiquitous Computing Applications

The past decade (1995-2005) of Computer Science research has generated many applications and architectures to support Mark Weiser’s original vision of ubiquitous computing or one of the many variants. Here, we present applications for everyday environments, including educational, the workplace, and domestic environments. Information awareness can be achieved through lightweight information applications and ambient displays. The architectures that follow emphasize the implementation of a particular area of ubiquitous computing architecture: services, connectivity, software infrastructure, and toolkits.

2.3.2.1 Everyday Environments

The most common of everyday environments are those where we learn, work, or sleep. At one end of the educational spectrum are college students on a university campus, at the other end are the children attending kindergarten at their local elementary school. The Classroom 2000 project [2] and the Smart Kindergarten prototype system [190] are two ubiquitous computing applications designed to support students in their native learning environment. The iLAND environment and novel Roomware form factors [194, 197] are work-place applications to facilitate and support co-located or collaborative work. The WorkSPACE project [68] demonstrates a prototype to augment "ordinary physical objects of work" with "pervasive hypermedia interfaces". Domestic hypermedia [152] "merges digital spaces into physical spaces and vice versa". Next, a framework for domestic ubiquitous computing environments [163] is presented. Finally, the Philips HomeLab [153] and its first commercial product marketed to hotel chains, the Mirror TV [148, 31], are discussed.

2.3.2.1.1 Classroom 2000

In April 1998, Abowd et al. presented their ongoing work at Georgia Institute of Technology on their ubiquitous computing application in the everyday environment of a university campus [2]. The Classroom 2000 project served to capture and integrate the instructor's material that students were exposed to in their classroom lecture, such that it could later be "universally accessed…when and where they study". Class material included optional pre-prepared lecture notes (on slides that could be written over by the instructor); an electronic whiteboard and pen; and audio recording of the lecture. It was used in over 12 classes over an eighteen-month period of study, and is being continually improved for ongoing use in a demonstration of "robust systems that can be the basis of large-scale and long-term studies". The authors discuss the four phases of the Classroom 2000 system: pre-production, capture (live recording), integration (post-production) and access; and the qualitative results from evaluating student and teacher questionnaires, interviews, usage logs, and captured lecture materials. They wish to demonstrate through their research how ubiquitous computing technology can positively assist teaching and learning in an educational environment.

2.3.2.1.2 Smart Kindergarten System

In July 2001, Srivastava et al. at University of California, Los Angeles discuss the key technology challenges and issues in developing a prototype environment called the "smart kindergarten" [190]. This classroom will be filled with the typical physical objects expected by the children that inhabit it during school hours. However, each toy is embedded with sensors and wireless communication and processing capabilities which are networked together in an unobtrusive and seamless manner within the "deeply instrumented physical environment". Additionally, automated or manually controlled cameras, microphones and badges will provide further means for capturing the activities of the target users in their "real-time reactive environment". The authors present and discuss the proposed system architecture design, including required networking (for example, Bluetooth and wireless LAN), software infrastructure (using middleware like Jini), and data management (such as Bayesian Belief Networks) issues. The goal of the researchers: to investigate "how wireless information technology can be integrated into early childhood education and assessment" to realize their vision of "educational applications to integrate student-level assessment as a formal component of the application… the idea of individualized student feedback on an ongoing basis to promote the development of math skills".

2.3.2.1.3 i-LAND and Roomware

In May 1999, Streitz et al. in Germany published a paper on their first prototype of an "interactive landscape for creativity and innovation", which they refer to as i-LAND

[194]. This environment is their vision of future workspaces. One goal is to provide flexibility for collaborative teams and individuals to dynamically configure or reconfigure the layout of their workspaces as needed, when needed. The idea is to integrate information interfaces into architectural spaces such that everyday mobile physical objects can be used in innovative ways to enable and support the differing work practices of their tenants. To this end, they present example scenarios of how innovative workspaces might support impromptu meetings between coworkers, and how a collaborative team might split into subgroups to work. Results from an empirical study of potential users were used to “inform” their design of innovative tools and components. The “roomware” may be a piece of furniture or a novel form factor. Together they are used to build “idea spaces” for “creative teams”. The authors describe the roomware, software developed in Smalltalk, and both the software and technological infrastructure required to support this first realization of i-LAND.

At the end of 2002, Tandler, Streitz and Prante published a paper describing the second generation of roomware [197]. Designing for the two goals of “direct human-information interaction and human-human cooperation” requires the computer to “disappear” from the user from both physical and mental points of view. A new component called ConnecTables was added. The DynaWall, CommChair and InteracTable were redesigned. Using roomware, users are able to “tailor and compose them to form cooperation landscapes”. The authors describe the design of each piece in terms of a physical description and implementation, interaction techniques, and affordances of each piece to provide ubiquitous computing and support collaborative work for the users. They also describe their software framework and infrastructure called “Beach” (for Basic Environment for Active Collaboration with Hypermedia). Their application model is organized along three dimensions with five separate models for interaction, environment, user interface, application, and data models.

2.3.2.1.4 WorkSPACE and Physical Hypermedia

In August 2003, Gronbak et al. introduced a physical hypermedia system to augment common workplace objects with “pervasive hypermedia interfaces” [68]. The prototype was developed within the WorkSPACE project, using materials typically found in a work environment for landscape architects. The goal of direct linking of *tagged physical artifacts* with related *digital information* stored in a spatial hypermedia system was to provide “seamless support” for the organization and management of mixed materials. For example, designers could physically tag selected objects on an interactive desk or augmented wall, enabling tracking and preventing later inconvenience of accidental or “temporary disappearance” of important materials. Ethnographic and empirical studies were conducted to inform the initial design. The initial prototypes were tested (by four landscape architects) during a three-day workshop. The users were observed while performing their design task and provided further feedback via “elaborate discussions”.

In August 2004, Petersen and Gronbak published a paper on physical hypermedia in the home environment [152]. The dimension of context-aware hypermedia [74] is an important addition to the requirement of spatial hypermedia as the goal here is to “support seamless context-dependent presentations for the inhabitants moving around the home.” An empirical study of six homes was conducted prior to the design of a “novel home appliance” called MediaTable. Each family member can collectively take part in organizing “family” digital materials; enabling each member to become explicitly “aware of new materials” and thus avoiding the scenario of digital materials of interest becoming lost in a computer “without reaching the attention of the rest of the family”.

2.3.2.1.5 Disappearing Computers

In a March 2005 *Communications of the ACM* article, Russell, Streitz and Winograd discuss the status of separate projects that integrate large displays into “interaction areas” with the same goal: “to make the computer as a device ‘disappear’” [172]. The first project, iRoom, has gone through multiple configurations at Stanford University since 2001. It is furnished with a variety of interactive workspaces such as the

Interactive Mural, Interactive Table, and iStuff [9]. Research groups use it as an actual workspace for various research and teaching activities. Next, an update of Roomware [197] is given. Initially developed in 1997, the collection of devices can be configured for use in private meeting rooms or semi-public lounges. Finally, the IBM Blueboard interactive plasma display, where target users are individuals or small co-located groups, is discussed. In July 2005, Streitz et al. published an article with more information about "The Disappearing Computer" initiative [195].

2.3.2.1.6 Domestic Environments

In April 2003, Rodden and Benford at the University of Nottingham in UK presented a framework for designing domestic ubiquitous computing environments [163]. They noted the current research in the area focused on three major areas: understanding domestic environments, digital devices designed for use within domestic environments, and technology and infrastructure issues. The authors posit a new point of view incorporating Stewart Brand's evolution of buildings theory. They take Brand's six defined layers: site, structure, skin, services, space plan, and stuff; and discuss the people, processes, and representations of building evolution that can occur over time and how they may affect "development of interactive digital devices for domestic spaces". Additionally they overlay the existing research activities over their framework to provide a point of reference to help other researchers identify where their work fits in. They hope this will facilitate coordination of efforts between all researchers interested in the area of ubiquitous computing for domestic environments.

2.3.2.1.7 HomeLab and Mirror TV

Located in The Netherlands, Philips HomeLab was established in 2002 as a "research incubator for future electronic products and technologies" [153]. The home is a modern residential facility that doubles as a scientific research laboratory. Residents who stay at the home go about their daily lives, with the added convenience of new technologies made available for their personal use. The individuals or families, who may stay anywhere from a couple of hours to a couple of weeks, are observed for their interaction with prototype devices by researchers via cameras hidden throughout the home. The Philips goal of “Ambient Intelligence culture” is to provide innovative products that will meet the needs and improve “people’s everyday lives” with technology that is “embedded and easy to use”.

The first commercial product from HomeLab was announced in June 2003. The Mirror TV is a mirror with a specially laminated LCD display integrated into part or the whole mirror [153]. When the LCD is off, the Mirror TV looks and acts like a conventional mirror. When switched on, the LCD display portion of the Mirror TV is very versatile, acting as a television, or even a LCD monitor for a laptop. The initial marketing to high-end hotels will enable Philips to produce customized Mirror TVs on a small scale for each customer by size and décor [148]. The product was initially developed in response to space constraints of hotels and cruise ships [31]. According to the company, its hidden electronics design provides “upscale ambiance” and an “architecturally refined display” [153], which should make for more pleasing environments.

2.3.2.1.8 PlaceLab

In July 2004, PlaceLab [95] opened as a 1000-square foot research facility in Cambridge, Massachusetts. In this condominium, a single person can be studied over a period of days or weeks using the various technologies that have been built into the living space. Aside from being used for specific research protocols, the context-aware, ubiquitous devices in the living lab will provide a library compilation of “everyday activity” data in the form of sensor readings, audio recording, and video recordings.

2.3.2.2 Information Awareness

Visualization in the form of lightweight information and ambient displays are two ways users can be made aware of peripheral information in their immediate environment. Users are not required to explicitly interact or attend to the display medium itself unless and until they choose to. While most designers use the terms ambient and peripheral displays interchangeably, Plaue et al. [154] distinguish between ambient and peripheral displays by how much awareness information is being communicated. They state peripheral displays may present more than one information item at the same time, while ambient displays present only one.

2.3.2.2.1 Lightweight Information

Examples of lightweight information displays include tangible bits [97], informative art [84], semi-public displays [86], and ambient slideshows [30]. Tangible bits focuses on merging computing with the physical environment [97]. By associating specific information with various ambient media (light, shadow, or water flow) commonly available in the background, peripheral senses can be employed by the user in determining if and when attention needs be shifted towards it. The key is the ability of the user to monitor the peripheral information in the background, without needlessly distracting them from their primary task at hand in the foreground.

Informative art [84] is an example where slowly evolving dynamic information is displayed as traditional artwork around the home or workplace. Each piece of art is designed to specifically resemble a well-known style. For example, the four applications in [84] include informative art displays depicting the following information: weather updated every minute for six cities, level of activity in a room, previous month's history of earthquake levels, and passage of time. Because the information is displayed in a slow and continuous manner, it may offer a composite "overview" of the data that is not otherwise readily apparent or available to the viewer in a composite manner. The authors, Holmquist and Skog, cite current research in emerging technologies that will soon result in more appropriate forms of displays than the projector used in the installation (or flat panel screens easily available today). In fact, traditionally thought of displays may eventually be eliminated altogether. There may come a time where any surface can be used as an informative art display. Although the aesthetic nature of the information visualization is an important component, the stated goals of the research were: to study the deployment and use of "art as an information medium" and "explore news ways of introducing information displays in the everyday environment".

The use of a semi-public display in a lab environment by a group of co-located workers [86] is also an example of a lightweight information display. It helps group members to know the whereabouts of each other, such as their presence in the lab or plans to attend scheduled events, in an unobtrusive manner that protects their privacy. A collaborative workspace used for "asynchronous brainstorming" is provided, as well a persistent space reserved for group "reminders". Each application is displayed as part of a montage projected onto a SmartBoard during the times it is not being used for meetings.

Collection Understanding [30] provides streaming collage, image thumbnails, and ambient slideshows as visualization tools to help people come to an understanding of image collections. The ambient display of a group of images in the background allows them to become "immersed in the environment" such that no explicit interaction is required. This, in turn, allows for a gradual understanding of the entire collection over a period of time, without the need for continual direct focus.

2.3.2.2.2 Ambient Displays

Ambient displays and their evaluation have received some attention over the last several years. In April 2003, Mankoff et al. [124] proposed a set of heuristics to evaluate ambient displays. Their goal was to provide a set of guidelines to effectively inform ambient display designers on how to improve their work. The following year, Matthews et al. [128], also from UC Berkeley, present a toolkit to support building of peripheral displays. In April 2004, Holmquist [83] introduced a framework that emphasizes "comprehension over time" as a required factor for evaluation of ambient displays. He stated before a user can understand an ambient display, the user must first "know" it is a display; understand "what" information is being communicated; and finally, understand how the visualization itself relates to the information being communicated. In May 2004, Plaue et al. [154] present a study to evaluate a peripheral display on a single dimension: its effectiveness at communicating particular information. In April 2005, Consolvo and Towle [34] present results from a study evaluating an ambient display prototype in the home environment. In addition, they evaluated their prototype with the heuristics proposed by Mankoff et al. [124]. At the same ACM CHI conference, Jafarinaimi, et al. [99] present their ambient display design, and the evaluation based on "how interactions over time with an ambient display can potentially change human behavior".

2.3.2.3 Architectures

The ubiquitous computing prototypes that follow emphasize the implementation of a particular area of ubiquitous computing architecture: services, connectivity, software infrastructure, and toolkits. The Ubiquitous Storage Architecture [24] provides a reliable backup service of mobile data. The Wireless Convergence Architecture [142] provides a means for automatic and uninterrupted connectivity when traveling from one space to the next. Two examples of software infrastructure architectures are the Centaurus System [102] and the CINEMA System [14]. While the first prototype architecture provides seamless integration of services for wireless devices in smart spaces, the second presents ongoing research to develop a "global scale ubiquitous computing architecture based on open standards". Finally, the iStuff toolkit [9], developed at Stanford, and available as open-source to third party researchers, is discussed.

2.3.2.3.1 Ubiquitous Storage Architecture

In March 2001, Burge et al. published work ongoing at Howard University on a prototype framework of a reliable backup service of mobile device data and its associated backup protocol [24]. Upon a positive indication of the availability of a mobile storage device at the user's current location (service discovery), the backup process of a user's mobile device is automatically initiated. Data is wirelessly downloaded to the mobile storage device from the user's mobile device. At some further point in time, the mobile storage device initiates and sends the user's data from the temporary mobile storage device to the user's "home" machine or the user's Internet-based data repository. The prototype implementation uses infrared wireless communication and the Java-based Jini, the authors describe as "network-enabled service architecture that provides plug-n-work capabilities to devices and services… in a distributed pervasive environment”. They discuss privacy and security related issues, as well as the backup protocol to provide “transparent reliable eventual delivery” in the event of an unexpected failure. The primary intent of the authors is to be able to use the mobile storage device as “a gateway for pushing and pulling content, to and from the mobile device and primary machine”.

2.3.2.3.2 Wireless Convergence Architecture

In August 2002, Nikolaou et al. presented work in The Netherlands and Greece on the design of a wireless convergence architecture (WCA) [142]. The WCA consists of software for the mobile device, the network server, and a dedicated gateway/proxy machine. It provides an intelligent means for automatic and uninterrupted connectivity of the mobile device to the most appropriate network available during the user’s travel from one physical space to the next. For their prototype, they chose two technologies, the 802.11 wireless LAN for indoor or local communications, and GSM (Global System for Mobile Communication) for outdoors or wide area communications. The authors discuss two specific issues: (1) transparency of location, when the boundary of the current network has been reached and it is time to switch to another; and (2) how to support resiliency of wireless communication against breaks and termination of the connectivity. (The solution is to freeze the application until reconnection is established.) The authors discuss these issues, and present the overall WCA architecture. They also discuss their prototype network environment, prototype implementation on Windows NT (mobile device software) and Linux (mobile device and gateway/proxy components), and the testing scenarios used for evaluation of their prototype. They concluded positive results towards their “vision” of “allowing the user to move seamlessly in the resulting *virtual* world”.

2.3.2.3.3 Centaurus System

In November 2002, Kagal et al. presented their first implementation of their prototype Centaurus system, a software infrastructure to support seamless integration of "intelligent" hardware and software services for pervasive wireless mobile devices in "smart space" environments [102]. Before describing the framework, they describe a scenario in which a user can use his personal digital assistant (PDA) to order a cup of coffee and be notified where (in the near vicinity) and when to pick it up. This is an example of their goal, "building portals… to the world of 'things' that users can communicate with and control". The authors go into detail on the system design of the following components: transport prototcol, communications manager, service manager, services, and client. In addition they discuss the XML-style Centaurus Capability Markup Language (CCML) they have created for system-wide communications. Finally, they describe their prototype implementation written in Java (services and service manager) and C (client and communications components). While the Centaurus System will not be dependent on specific technology, the prototype provides for infrared, a CDPD modem, and Bluetooth communications modules. Two prototype services were created: turning on a lamp and playing MP3 music files. Future work planned includes implementing a recommender service. This service would display the specific services the user might be interested in based on his interests and the current local environment.

2.3.2.3.4 CINEMA System

In June 2003, Berger et al. at Columbia University presented their ongoing work on a "global scale ubiquitous computing architecture based on open standards like SIP and SLP" [14]. They also incorporate off-the-shelf hardware like Bluetooth-enabled devices and active badges. Specific issues the authors discuss include location of user, location information, service discovery, actions and events, access, privacy and security issues. Their prototype system is built on their previous research of the Columbia InterNet Extendible Multimedia Architecture (CINEMA) infrastructure for multimedia collaboration. Users may customize services and their working environment through a web interface, while multiple administrators also have access to monitor and configure lab rooms running the CINEMA system. The authors describe a SIP-based ubiquitous computing environment and describe a scenario of a user's visit to conference room at the University of Kentucky. Because of a “roaming agreement”, the user in the scenario is authorized to use local resources that would have otherwise been inaccessible to her as a visitor.

2.3.2.3.5 iStuff Architecture

In April 2003, researchers at Stanford University presented their work on a toolkit of physical ubiquitous computing interaction devices [9]. The toolkit, called iStuff, is built on top of iROS middleware, also developed at Stanford. The purpose of the toolkit is to be used in rapid prototyping of new and innovative physical user interfaces that do not resemble traditional desktop graphical user interfaces. Each iStuff component consists of a physical device, a homemade or off-the-shelf lightweight wireless (infrared or Bluetooth) input/output device, and its software proxy. Applications dynamically map the desired iStuff component(s) through a PatchPanel. The authors describe the iStuff architecture that includes components, event communications, and the PatchPanel. They then classify iStuff devices in five dimensions to define the “design space” of their toolkit. The dimensions are (1) direction: input, output, or both; (2) modality (human sense used): manual, auditory, haptic, visual; (3) resolution: binary (single) value, fixed-range values, or infinite range of values; (4) dimensions: 0, 1, 2, or 3-D; and (5) relative or absolute (change). Several example uses of the toolkit by other researchers and students at Stanford are included. iDog, in particular, is a prototype “created in an attempt to inspire applications… one of the original goals of the iStuff project”. The iROS middleware software is open-source and the iStuff designs are also available for free. These are the only two components required for third party researchers to use the iStuff toolkit, which the authors would like to encourage.

In April 2004, Glesner et al. [63] introduced a “reconfigurable architecture” design called Systems-On-Chip. This advancement in architecture, and the other examples listed above represent only a fraction of the recent initiatives in ubiquitous computing applications. To emphasize the importance of applications in ubiquitous computing research, the ACM Symposium of Applied Computing started a special track on

Ubiquitous Computing in 2004 [169, 168]. The co-chairs stated a "philosophy" based on "application-driven research… is essential for the ubiquitous computing community." In May 2005, Roy Want (who previously wrote an article in tribute to Mark Weiser five years earlier [211]) and Pering presented an update on what system software challenges [212] still remain. At the same CHI conference, "social implications of ubiquitous computing" received attention as a separate workshop for the first time [35].

2.3.3 Computing and Art

Computing and art encompasses a wide range of applications and projects, including using the computer as a tool for making art, displaying art in a traditional or non-traditional way, or "being" part of the installation of art. combinFormation [108], previously known as the CollageMachine [107, 106], is a dynamic "art making" tool that creates "recombinant visualizations" from heterogeneous information elements. The Digital Art Museum is an online showcase of "new and emerging" work of contemporary digital artists as well as the history behind computer art [109]. Computing as installation art presents nontraditional challenges. Charlton [32] discusses why the screen (monitor) separates the information it is presenting from the surrounding objects instead of becoming integrated into a "seamless whole" with the installation. This may very well change with the introduction of OLED displays.

2.3.3.1 Recombinant Information

In November 2003, Kerne et al. at Texas A&M University introduced their latest research on recombinant information, a tool called combinFormation [108]. combinFormation is the "next generation" of Kerne's work on CollageMachine performed at Texas A&M and earlier at New York University Media Research Lab. In October 2002, Kerne presented an innovative CHI interaction concept-context-design model [107] illustrated with specific examples from CollageMachine experiences. CollageMachine is an "art making" tool such that the user may specify an area or subject of interest, from which a "streaming collage" of website images and text are dynamically generated and displayed on a grid. The user may then use various browser tools to interact with the changing collage and actively “steer” it into the direction of his personal interests. The visualizations created by CollageMachine provide an interesting alternative view to traditional browsing methods of following specific links predetermined by a specific person (the author of the webpage). For example, a collage based on the websites of a newly formed small group of collaborators can lead to an increased mutual understanding of their individual work and/or interests in relation to one another, and help them get acquainted in a shorter time frame than might be normally required. Kerne’s September 2001 paper [106] on the CollageMachine describes this in another way. The result of recombination and juxtaposition of various media elements in the collage is to change the environment, and thus the context. The change in context further leads to a change in meaning.

2.3.3.2 Digital Art Museum

In October 2002, King presented a paper on an ongoing effort to create an online digital art museum that showcases the “new and emerging” work of contemporary digital artists as well as the history behind computer art [109]. The history was divided, and is being archived, in three phases: pioneers (1956-1986), paintbox era (1986-1994), and multimedia era (1995 to present). The dividing line between the first two phases, 1986, was named for the Quantel Paintbox system, and was chosen in part because Photoshop was developed that year. The break at 1994 between phases two and three, was set at the point in history where the WWW became popular. This paper focuses on phase one. The author lists and highlights selected “pioneers”, some who had primary occupations that were not “artist”, but mathematician or scientist. In addition, he surveys the major modern art movements that have had an impact on these computer artists. In looking at the historical picture as a whole, King observes, “none of the digital art genres became a significant art movement”. He concludes, “it may still be true that there are no great masterpieces of computer art, but there certainly is a substantial body of fine work that can stand as art”.

2.3.3.3 Installation Art

Also in February 2003, Charlton published an article in the Internet journal called *First Monday* [32] to investigate why screen media ostensibly remains a "separate" part of installation art. In other words, why the screen (monitor) separates the information it is presenting from the surrounding objects. The goal is that the monitor be integrated into a "seamless whole" with the installation, such that the screen becomes the installation. There are three components of installation art: the apparatus, image, and space (installation). The apparatus is the presentation device that provides a frame for the screen, whether it is visible or not. (For example, for a projector, the frame is the "space" between the physical device and the surface that is being projected upon.) The frame is required to separate the screen image from the exterior space (installation). Thus, the image relies on the frame of the apparatus for its form and is thus site specific to the apparatus, but is premised "elsewhere" at the location of the image source, whether it is known or not. The installation is premised "here" and is site specific in regards to space and time. The installation is where the viewer and apparatus are located.

The viewer must exist for the installation artwork to be "activated"; the viewer connects the two spaces of the screen image and the exterior installation. It is the job of the artist to integrate the elements of screen image, installation and viewer such that they "share the same interiority". In other words, the goal is to bring image and installation (space) together such that they are located within each other, requiring the viewer to interact with only one site. The Internet is an example of such a site: "viewers and location are brought together… as their content is specific to one location and applicable to all". The content must be active and address the location, and at the same time, location must include both the content and the media. Charlton cites Net.Art as an example of an installation on the Internet that meets these criteria. The definition of the term Net.Art has "been adopted to define what by nature is a diverse intangible practice that uses the

Internet as a site of both content and media… every monitor, every room, every user connected to the Internet is part of the installation". He describes three projects that turn "the viewer into content", creating a "feedback loop" within the installation art. It is in providing for interactivity of the viewer that the artist achieves the "seamless whole" such that the screen, the installation, and the viewer are one in installation art.

2.3.4 Interactive Storytelling Engines

The art of narrative storytelling has evolved with advances in technology. The advent of commercial word processing applications first provided the storyteller an alternative to using the traditional two-dimensional paper medium and supported the basic linear structure of a story (the topic, introduction, chain of events, and the closing elements) well. According to Ong and Leggett, "writing a good story requires immense patience, creativity and work from the author, and the practice of writing a story still requires a good grasp of the readers' psychology in order to create suspense and thrills and to merge the readers' world with that of the story" [146]. While the foundations of good storytelling principles have remained unchanged by advancing technology, opportunities to author using digital media and state-of-the-art presentation techniques are now available even to the inexperienced storyteller through digital writing spaces.

The history [232, 23, 28] and current research on interactive storytelling systems has seen a wide variety of paradigms, some of which overlap. Immersive storytelling [136, 78], emergent storytelling [7, 38], plot-based systems [122, 178,64], interactive story authoring [15, 36], and character-based systems [76, 16] are the major approaches. Those involving synthetic actors may be of special importance to the development of the next generation of interactive storytelling systems [127]. Narrative intelligence [126, 175] applications and authoring tools are the two main focus areas of the various research approaches, the latter of which is discussed next [145].

Recent research efforts in authoring tools for interactive storytelling make use of advanced animation, visualization, simulation, and virtual reality techniques and technologies [146]. Glassner's [62, 61] research on story contracts describes the need for story structure in interactive fiction design to encourage a positive experience for the reader. Sgouros presents the CHOROS environment for authoring, annotating and directing robotic actors through their performance of a narrative script [177, 176]. Storytelling engines offer new and innovative techniques that may allow the reader to influence how the story evolves, or perhaps allow the same story to be retold with multiple recombinations of the various story components, resulting in a different twist each time [146, 145]. Brooks [22, 39] proposed the use of a storytelling engine to support a new form of narrative: the Metalinear Cinematic Narrative. His environment provides contextual feedback helpful to the storyteller during the authoring process.

2.3.4.1 HEFTI

Work by Ong and Leggett [146, 145] ongoing at Texas A&M University, introduces a new template-based search approach for their "hybrid evolutionary-fuzzy based" interactive storytelling engine. Advantages include increased flexibility and robustness by the author to control and customize narrative rules for the Genetic Algorithm [132]. The HEFTI Interactive Storytelling Engine is designed to be a "cyborg" authoring environment such that the human author has at his disposal various digital writing tools and materials which enable him to simultaneously write and "conduct" the performance of the characters within the story. The author may specify or modify rules, templates, and scripts of the story that are stored in the knowledge base. The storytelling engine uses these elements to construct stories that are narrated to the reader with visual graphical characters and display of the associated story text. The author may then interactively modify custom parameters to generate new story scenarios. For example, the story of "The Three Little Pigs" and its four main characters can be "read" over and over again, each time with a different fate for one of the main characters. Further applications for the storytelling engine besides telling narrative stories, is its potential use in an educational setting to teach math or science. Another ideal application would be to use the engine for other entertainment purposes, such as computer game playing.

3. DISPLAY COMPUTER VISION

Display Computers are for everyday people in everyday environments. For this reason, we have chosen to focus our work on families. What will mom and pop need in their everyday environment to make their lives easier and more enjoyable, hopefully leaving them more time to spend with the kids? What will children need to help them learn and participate in all of their multiple environments in a manner that takes advantage of all the latest technology the world has to offer? How can we include those extended family members and friends who live a considerable distance away in our lives so they know they are constantly in our thoughts and have our best wishes?

In his book, *Leonardo's Laptop*, Shneiderman suggests "visionary insights come from thinking more about human needs than technological possibilities" [185]. In this chapter, we will present various scenarios of use enabled by the advent of Display Computers. These new paradigms of use are based on the human needs of the Display Computer users: the children, moms and dads, and extended members of families.

Let us first briefly revisit the subject of Display Computers. Alan Kay and Mark Weiser are two visionaries who had a tremendous influence on shaping the Display Computing paradigm and the focus of families and children as the scope of this research.

The vision of Kay and Goldberg's "personal dynamic media" -- the Dynabook -- was to provide a computer as a tool that "could be owned by everyone and could have the power to handle virtually all of its owner's information-related needs" [103]. Note that "everyone" included children as computer users, a novel idea at the time. Though designed to go unnoticed, the computer is an integral part of a DC. (The other integral part being the display, of course!) Like the Dynabook, a DC can be thought of as tool that can be owned by anyone, including children. However, it is not an all-in-one tool like the Dynabook. As an explicit or ambient information tool, a DC will provide only as much information as is relevant or pertinent to the object or form factor it resides on. However, it is not difficult or far-fetched to imagine a world full of DCs to meet our needs in the future.

Thus, a DC might serve as an explicit information management tool in the traditional sense. Such a DC will take shape as a novel form factor to provide a lightweight tool that is both affordable and convenient to use. Equally, or perhaps even more interestingly, will be DCs designed in novel ways to provide ambient, calm technology [223, 224] using common household objects. For example, everyday objects, such as a kitchen timer or an alarm clock, may be transformed into DCs for children to serve as toy-and-information-tool-in-one, to help them with their everyday life activities in a fun and lightweight manner. The opportunities Display Computing brings to the table are thus two-fold: (1) as novel delivery platforms of traditional applications, and (2) as providers of previously unimagined and novel computing applications on common, everyday objects, old and new.

Mark Weiser stated the premise of his ubiquitous computing paradigm as follows. To fully and most effectively take advantage of *computer technology*, we should embody it into the *objects* we use on a daily basis in our lives. Particularly useful, would be to *embed computers* into those objects that play a role in *communicating symbolic information*. Since objects come in all shapes and sizes, in varying qualities, they should be so *affordable* as to be accessible to every member of society, and thus "*bring computing to everyone*". [217] Let us take a closer look at how Display Computers fit each of these main points.

DCs as computer technology. Recent and ongoing innovative advances in computer technology research and development will allow visionary new computing paradigms to become reality and thus enable new paradigms of use.

DCs as everyday, affordable objects that communicate symbolic information. Everyday household items, appliances, and even toys will be transformed into DCs to help children and adults alike with all of their information-related needs in the near future.

DCs as embedded computers. The computer technology embedded into an everyday object will provide explicit or ambient information-related tools unique to the form factor. In a DC, the computer is manufactured so as to be effectively invisible to the user; the user will simply notice the display.

DCs will bring computing to everyone. Alan Kay has dedicated his research to focus on children as computer users. Also important are the caregivers of the younger user group: the adults in their lives, including parents and extended family members, who may or may not have had the opportunity to have access to computers previously.

3.1 Display Computing

The term Display Computer (DC) at first glance seems easy enough to define: Display Computer = Display + Computer. The "Display" part is the standard viewing surface found on everyday objects that conveys information or art and is found in everyday environments, indoors or out. The "Computer" is found on the same everyday object, but by its ubiquitous nature will be relatively unnoticeable by the DC user, as it is manufactured "in the margins" [117].

Some fundamental characteristics of Display Computers are also easy to list. A Display Computer is a mobile computer [121], it moves with us as part of the everyday object. A DC is a ubiquitous computer: "effectively invisible" [217], available at a glance, and seamlessly integrated into the environment [218, 219]. A DC should be an example of Weiser's calm technology [223, 224]: encalming to the user, providing peripheral awareness without information overload. A DC should provide unremarkable computing in support of our daily routines in life [202].

But Display Computing requires a totally different way of thinking. It is difficult to disregard our learning and experience with the traditional desktop metaphor. This is not a new problem in the history of Visionary Computing. Researchers who chose to follow the visionary ideas of the past have always had to learn to think in radically different ways.

Weiser dedicated one essay [221] to reflect upon commonly used metaphors for describing traditional interaction with computers. He concluded there was not one that appropriately emphasized invisibility such that the computer is not the center of attention. He proposed using the childhood metaphor to describe ubiquitous computing. “I propose childhood: playful, a building of foundations, constant learning, a bit mysterious and quickly forgotten by adults. Our computers should be like our childhood: an invisible foundation that is quickly forgotten but always with us, and effortlessly used throughout our lives.”

We propose to use the childhood metaphor for Display Computing. To take it a step further, we also recognize the unique opportunity that exists to design for those users still in their childhood years. Children are constantly learning about their world and how to live in their world. When asked what they *want* to do, they usually reply, “to play and have fun!” Translated: this invariably means having the freedom of choosing what they want to do. However, since this is not always possible, we can and should provide them with everyday and unlimited access to the “toys” children can play, have fun, and learn with, all at the same time. The visionary computing ideas of the past and present, coupled with current and future technological advancements, provide ample foundations to enable children of this generation to soon find themselves living in a environment that is enriched and saturated with DCs for their every need and want.

3.2 Children, Playing, and DCs

Designing for children as a user group was primarily neglected until discussed by Kay and Goldberg in March 1977 [103]. They realized that children as users of computers had unconventional requirements, including interactivity, flexibility, and the need for exciting visual displays. These qualities would help the children keep their attention focused and interests up. In a recent interview conducted in May 2003, Kay reiterated some long-standing views on children and computing [21]. With the computer as a tool, and education as the key, the objective was and still is to provide a rich environment to provide optimal learning conditions for children.

Kay stated: "play is the most important means of learning, and so you want to harness it for as many years as you possibly can. Play is nature's built-in mechanism for the child's deepest learning. And if the environment isn't rich enough, you lose the element of play. But if you make the *environment rich* and *keep the play going*, then you win in a big way. Because maybe the biggest question about education is, *'What is this kid going to do when teachers and parents are not around?'* If children love the learning process, they want to *spend all their time at it*." (Italics were added for emphasis.)

In October 2003, an Ubicomp workshop [204] paper discussed play in relation to ubiquitous computing research [13]. The authors suggest that knowing when, how, and why, about the "human tendency to play" can and should be taken advantage of when designing for "usability and utility". They observe that human play can be characterized as seamless: "humans seamlessly move in and out of the context of play". Play encourages learning by exploration with an added benefit of lowering prior expectations. "It is during play that we make use of learning devices, treat toys, people and objects in novel ways, experiment with new skills and adopt different social roles."

Currently, many children in our society have access to computers through school and learn how to use them in a laboratory environment, unless they own or have access to either a personal computer or a laptop computer at home. The traditional desktop metaphor and applications available today dictate that the minute the child sits down in front of the computer, he is immediately transformed into a "mini-adult" [117] computer user, no matter if they are five, eight, eleven, or 18 years old!

The school curriculum teaches academic and educational uses of the computer, such as how to use Google to find information on the Internet, Word to create documents, or PowerPoint to make slides. They also may provide access to child-safe email [58] accounts. At home, children may use the computer to finish their homework assignments, but would much rather use it for "fun" recreational time to play computer games or to surf or "google" the Internet as suited to their own personal interests. Many entertainment sites are dedicated to children, such as Disney [42] or Nickelodeon [141]; information sites for sports team rosters, scores and schedules [49]; and to the delight of one five-year-old, even the opportunity to find the lyrics and the actual song being used in dance class [229]!

While the computer as a tool for information or entertainment is useful and necessary, Kay cautions their use solely for the presentation of accepted facts. Sitting in a chair in front of a computer discourages a child's physical interaction with other people and limits their interaction with objects in their immediate environment, including those typically used for play. Display Computers offer new opportunities to bring computing to children with the goal of "amplifying" the learning process, making learning fun, like playing [21]. With the advent of DCs, the subjects that can be learned by children are no longer limited to traditional information in the form of accepted facts and knowledge.

Acquiring the life skills needed by children, such that they will become more and more independent as they grow older and eventually turn into self-supporting adults in the future, is not an overnight or academic matter. It entails learning by trial and error, practicing good organizational and decision-making skills. Most of all, it takes time. While some adults carry around PDAs, many use tools on their home and/or office computer to help them in their quest for daily life management. These computer applications may be various combinations of information management, time management, or financial management tools.

What is available for children? They may not have the reading skills, knowledge, or access required to use applications targeted to the adult user. And in fact, the needs of the child for such tools are probably much greater than that of the adult: they need to *learn* these life skills, and practice them at every opportunity, hopefully improving through repetition and positive reinforcement. Based on their age and personality, they may depend on their own innate organization skills at first: by memory, writing notes, or possibly by using a calendar. Or, they may rely on others: listening to the teacher's explicit instructions for assignments, or depending on mom or dad to remind them of upcoming events and responsibilities. Yes, mom and dad should be there to guide them, but in the interest of less nagging and more actual practice, giving children easy access to helpful tools would be instrumental in making it easier for them to learn necessary life skills in a lightweight and fun manner. Display Computers can be such functional tools for children.

DCs for children should take the form of fun and useful everyday objects or toys. Playing and learning with a DC toy should be fun! A DC toy should be personalized to the personality and age of the individual child, instilling in them a sense of pride in ownership. A DC toy should provide timely feedback, such that the child is encouraged to keep playing, whether be it on a short-term time-scale (i.e. minutes, hours, or over an evening), or over longer periods of time (i.e. a week, month, or semester). This will help the child maintain his motivation to attain set goals and keep up with his daily responsibilities. A DC toy should provide lightweight and ambient feedback, making it fun for a child to check his own progress and provide him with a sense of accomplishment when a goal has been reached. Perhaps the DC toy could then serve as a reminder or trophy!

A child can have anytime access to specific information, such as the notion of "time". The ambient visualization of real time passing can be helpful in learning the value of time and judging how much time is left for or until a specific activity is supposed to occur. These features should help a child learn how to make daily decisions on what activities they should embark on, when, and for how long. Eventually, with practice, positive reinforcement, and parental encouragement, they should learn about personal responsibility and routines over time. Thus, making DCs available throughout the child's environment can encourage the mastery of information and time management skills, organizational skills, and goal management and at the same time, can be fun, rewarding and provide a child with self-satisfaction and a personal sense of accomplishment.

3.3 A Personal DC Vision

While categorizing children as a user group to discuss abstract concepts is good and well, everyone who has a child or is around children on a regular basis knows they come in different shapes and sizes, with different personalities, preferences, and aspirations. Designing one DC toy to fit each and every one of their needs would not be possible. Just as one would pick a particular birthday gift for a particular child, so would one choose DC toys to match a child based on his personality and age.

As a parent of three young children, ages 5, 8, and 11, I recently came to a realization that much of my interaction with them involved information management, including some dimension of time. It was my job to ask, tell, or remind each child what they should be doing, and what they had to look forward to, based on their own individual schedules. This seemed to be an unusually trying time, probably because a new school year had just begun. The oldest child changed schools, and the youngest child started kindergarten. Not withstanding the interruption of school routines the summer vacation had caused, it seemed like a struggle to get back into a daily routine of getting to school, doing homework, making it to extra-curricular activities, and going to bed.

In retrospect, the children and I did not recognize that old and new expectations of their behavior and actions were being placed upon them in an attempt to form new routines as required by a new school year. Complicating matters further, each child needed their own routine, based on their changing individual needs, and our needs as a family. *How could our lives be simplified with the help of some DCs?* After all they are for everyday people living everyday lives, like our family! (See Family-Centered Scenarios, below.)

I was once again reminded that "visionary insights come from thinking more about human needs than technological possibilities" (Shneiderman, [185]). So, it seemed I was asking the wrong question. It should not be, what can DCs do for us, but rather, *what do we need help with right now? For each child, what are the needs or challenges they are facing at this point in their life?* In the scenarios below, I introduce my vision of a DC world filled with DC toys. Eventually there would be a DC toy in Santa's workshop to meet every need of every child. However, here are some examples that would meet the needs of the three children in my life.

3.3.1 Five-year Old

Time is an abstract concept that is difficult for children to grasp. Learning how to read a clock well is only one step. They also need to understand that activities take varying amounts of time. Fun activities seem to take a lot less time than those that are not. So, whether a child is having the time of their life or sitting around doing nothing, it is very easy to lose track of time. For some kids, an especially difficult and dreaded part of the day is that part of the evening right before bedtime. For parents, the transition from a later bedtime during summer vacation to an earlier bedtime during the school year is a difficult sell, especially if it is still light outside.

Each child in our household has a different bedtime, depending on their age. (This policy seems to sit best with the oldest child for some reason!) While it would be best to have a set time (i.e. 8:30 pm, 9:00 pm, 9:30 pm) every night, invariably it changes from day to day depending on the activities of that particular evening. So, the best way is to set the expected bedtime for the youngest child at some point in the evening, with the understanding that all other bedtimes will based on the first time. While they still complain about going to bed, the older two can easily look at the clock and determine whether their bedtime has arrived or not. The five-year old, the youngest, depends on mom or dad to remind her periodically that bedtime will soon be upon her. When the actual time for bed has arrived, her reaction (from total agreement to total disagreement) is mostly based on her current activity and those of her siblings, and thus determines the time and energy it takes her to actually get herself into bed.

What my five-year old needs, is an *ambient DC timer* in the form of a bedtime buddy. This would be an age-appropriate and fun toy, whose sole purpose is to help her prepare (mentally and physically) for the arrival of bedtime every night. Once set by mom or dad during the evening, it counts down the amount of time left until bedtime, displaying in a lightweight manner some concrete visualization of time passing in terms that a five-year old would understand. She could then easily carry it around with her and refer to it whenever she wants, without constantly inquiring, “Is it time to go to bed yet?”

While it can be a rush to get a fixed list of activities done in a small amount of time, the emphasis would be on providing calm technology. For example, if the required activities are to (1) get ready for bed (go to the restroom, change into pajamas, brush teeth) and (2) get into bed (it’s not as easy as it sounds!), then it would be good to highlight and display a “yellow zone”, say at 12 minutes prior for activity #1, and a “red zone" 2 minutes prior for activity #2. This would inform the child in a lightweight and consistent manner that the end of time is about to expire and bedtime is imminently near. The goal for the child owner of the bedtime buddy toy would be to accomplish tasks for #1 during the yellow zone and be in bed (with her bedtime buddy) when the timer finished, ready for mom and/or dad to tuck her in.

There are some fun ways to encourage getting to bed on time using the bedtime buddy. My daughter recently found the wind-up music box from the old crib mobile they used as babies in her closet. Our current tuck-in routine includes winding it up and letting it play once (it is attached to her bed's headboard). Having a designated bedtime song start playing automatically upon the exact arrival of bedtime (when the ambient DC timer goes off) and continue to play for a small amount of time afterwards would be a fun reward. Another would be to automatically "print" reward coupons that a child could save up and eventually trade in for a bigger treat, like new pajamas.

Having a bedtime buddy might also be helpful to reinforce and encourage a decent bedtime when traveling away from home, i.e. during Christmas vacation. Having established routines can help children adjust to different environments, and may even help grandparents get them to bed at a reasonable hour! My daughter loves stuffed animals. The ideal situation would be for her to be able to go to a store and pick out her own bedtime buddy, increasing her sense of ownership and responsibility in their joint endeavor of getting to bed on time every night.

3.3.2 Eight-year Old

Accelerated Reader, commonly known as "AR", is the most popular commercial reading management software used by K-12 schools for their reading curriculum, according to the Renaissance Learning (RL) company website [159]. Many school districts in Texas use the AR program. Students choose a book from the AR list, according to their current reading level range. They earn AR points based on the point value assigned to the book chosen and their AR test score. Children earn grades, rewards, and recognition throughout the school year based on the number of AR points they have accumulated.

At one school, for example, AR points turn into currency the children can spend at the AR store for various novelty toys twice a school year. Larger milestones of AR points (i.e. 50, 75, 100-point clubs etc.) are rewarded as they are attained. The student may receive various AR merchandise, including bumper stickers (for mom or dad's car), shoelaces, backpacks, and duffel bags; and/or special opportunities to help out around school. It could be the chance to read to a class (usually a favorite former teacher's class), be a science lab helper, or to read announcements on the public address system one morning as the school day starts. Every other Friday morning, students who have moved up to a new AR point club level during the prior two weeks have their name announced on the p.a. for the whole school (including their siblings!) to hear.

For many children, simply earning points to spend at the AR store and the recognition and rewards they receive at school are enough keep them motivated to read on a daily basis as encouraged by their teachers. More avid readers may compete with themselves (i.e. to "do better than last year") or classmates to achieve personal goals they have set for themselves. However, some students need additional help in staying motivated to keep reading on a daily basis, and keep working towards a specific AR goal. My third-grader could use such help.

What my eight-year old child needs is an *ambient DC goal tracker* to help him visualize his progress towards his AR goal on a daily basis. Such a tool, in the form of a toy trophy for example, could provide him anytime visual feedback of progress towards his goal, in addition to a reminder of what the ultimate goal is. On each occasion he earns additional AR points, he could "see" how far it advances him to the goal. It could help him stay motivated, and encourage him to put forth consistent effort towards his goal on a daily basis. With the ability to review his progress with regards to a specific time frame (i.e. how many points did I earn last week? last month?), he could adjust his plan periodically as to what he needed to accomplish in the remaining time (i.e. by Christmas vacation). Perhaps if he had gotten to a very slow start at the beginning, the feedback could serve to reinforce to him that the extra effort of the last couple of weeks was paying off. In the end, he could choose to "save" his trophy as a reminder of his great accomplishment of reaching a long-term goal over several weeks, months, or even the entire school year.

One way to "reward" good progress in the short-term is to highlight on the display the milestones toward the goal reached (i.e. 25%, 50%, 75%) in an ambient manner. Note that some children need positive reinforcement at more frequent intervals than others (perhaps every 10%). An enjoyable treat would be to automatically print a reward coupon as each milestone is reached. An extra-special reward coupon (a trip to Chuck E. Cheese?) could be printed when the end goal has been attained. In addition, an automatic e-mail to mom and/or dad might be a good reminder to them that they need to reward the child for his big achievement in a timely manner.

Of course, along with the ambient DC goal tracker, my eight-year old son could also use an *ambient DC timer* to help him enjoy his reading time a little more every night. I believe he would like one to wear in the form of a cool wristwatch, or perhaps a pocket watch to put in his pocket or wear around his neck. Or, he may prefer one in the form of a bookmark, which would be convenient to carry around in his AR book. One thing that is for certain, if he could go to a store and pick his own DC toys out, he would treasure them more and want to use them more. Personalizing DC toys to specific child owners in terms of age, personality and interests, will make them much more enjoyable and special to them.

The drive to succeed is different for every child, depending on his personality, interests, and environment. For some, it comes naturally. For others, by providing the proper tools in DC toys, it can be encouraged, nurtured, and eventually learned with practice and positive reinforcement. If a child has never reached the upper AR point clubs and the rewards that come with it, he may not have the experience or incentive to know how much he would enjoy the sense of accomplishment that comes with reaching higher goals. Hopefully after experiencing a few successes (or however many it takes), a child will eventually learn the ultimate reward of achieving a goal is the sense of self-satisfaction that comes with it. The hope is that the child may one day no longer need outside sources of feedback and motivation to help them succeed, but will find within himself the ability to achieve personal goals through a combination of his own determination and hard work.

3.3.3 Eleven-year Old

The biggest challenge my fifth grader faces in moving up to the intermediate school from the elementary school is time and information management. The change from three teachers in fourth grade, to eight teachers and seven class periods in a block schedule, places a multitude of new demands on him in terms of teacher requirements and styles, class subjects, homework assignments and projects due. It was not a question of "if" he could do the work. How to manage and structure his time to complete assignments and study for tests in a timely manner became a central issue. Another was timely communication with mom and/or dad about supplies or help needed for his projects. For me as a parent, without the regular weekly reports provided by elementary school teachers, his initial academic progress was destined to be a mystery until he received his first set of mid-term grades.

What my eleven-year old child needs, is a *DC info board*. It is a semi-public display for co-located family members personalized to a specific child -- his schedule, school responsibilities, extra-curricular activities, and interests. Like the semi-public display for co-located workers by Huang and Mynatt [86], it should provide various forms of lightweight information for all interested parties (the child and his parents) in an unobtrusive manner, in one central location. An important requirement that should be emphasized for the benefit of the child owner is that the notion of current time should be strongly tied in with the information to be managed. The idea is to provide calm technology such that all required activities are planned and can be finished on a schedule that is not rushed or at the last minute.

Like the original semi-public display [86], an ideal DC info board would be a large display divided into sections, to be customized with particular components to suit to a particular child. Perhaps if my son were to go to a store to buy his DC info board, he would choose the following four components to go on it: (1) automated DC calendar, (2) personal goals & accomplishments space, (3) message center, and (4) photo and art display space. The last three components are fairly straightforward. In the goals & accomplishments space, he may want to track his AR points, or number of soccer goals scored this season. In the message center, he could leave handwritten, audio, or video notes to himself, or one for mom and dad (and vice versa) (see Family Message Center, below). In the photo and art display space, he may want to display photos of his pet dog or recent special events (see Dynamic Photo Collages and Basketball Camp, below).

The *automated DC calendar* itself would be a large enough display to be divided into sections and personalized with custom calendar components. On a master calendar, mom could help fill in regular school assignments and after-school events, while special events or one-time items would be added as needed. Custom calendar components, such as (a) today, (b) this week, (c) this month, would display events from the master calendar highlighting a view that is updated in real time. That is, the calendar display and the real-time clock are synchronized to provide the child with an automated and constantly "up-to-the minute" view of the present date and time (i.e. "you are here!"). The view is a highlighted time window that matches the granularity for the corresponding calendar component and changes as time passes. For a "today" component, it might be a two-hour window on the 24-hour day. For a "week" component, it might be two-day window, i.e. today and tomorrow. The “month” component might highlight the current week with today and tomorrow highlighted further. In this way, the child knows exactly “where” in time he is, no matter which calendar component he is currently looking at.

When looking at the “today” calendar component, the ambient clock or time display should very clearly distinguish the parts of the day that are in the past, present (2-hour block), and future. If a child needs to study for a spelling test before dinner, he should know exactly what time it is now, how many words he needs to learn, and how much time he has to study. If he looks at the “today” component every 5 minutes, he will see he has 5 minutes less to study each time. The calendar is providing a lightweight visualization of “real time” passing in a concrete and consistent manner. The following day, the “today” calendar will have already refreshed itself and “moved” forward one day. Likewise, in the “week” calendar component, perhaps “today” and “tomorrow” will display the detailed calendar events for each 24-hour period, with only today highlighted, and the rest of the week’s events serving as an at-a-glance look-ahead and reminder of what is to come. For example, such a quick glance may reveal that Thursday night there is a soccer game, so my project needs to be completed by Wednesday night, even though it is not due until Friday.

Because the DC info board and automated DC calendar are both customizable displays, each child should be able to find the right combination of information management components to suit their particular needs. My fifth grader could use a fine-grained calendar of all of his responsibilities tied tightly with the notion of time. It is easy for him to start studying when told, and equally easy for him to find an excuse to get up from it. Invariably he gets distracted and loses track of time. Providing anytime and lightweight access to “where” he is in time could help him visualize the passing of time. Hopefully, eventually he would learn to manage and organize his time more efficiently. Instead of taking four hours (the whole afternoon) to study for a spelling test (including all distractions), perhaps he would find out 40 minutes total time is sufficient if he were to sit down and concentrate on the one task alone.

3.4 Family-Centered Scenarios

In the following Display Computer world scenarios, the focus is on how everyday people, families in particular, can interact with DCs in their everyday lives. Because DCs will saturate the everyday environment as displays, they may or may not require direct DC-human interaction depending on the functionality of the everyday object. New interaction techniques will be and should be developed to allow humans to interact with the DCs that surround them in a lightweight and unobtrusive manner. However, for the purposes of illustration, commonly used terms we are familiar with today will be used in the descriptions below. While the previous section focused on DC toys for children, the following scenarios are geared toward all family members. For example, the Family Message Center and Basketball Camp can be useful for parents and their children alike. The Interactive Map and Information Highway may be more applicable to older children, along with mom and dad. The Dynamic Photo Collage would be a great way for extended family members to feel more in-touch and less distant with their adult children and their grandchildren.

3.4.1 Family Message Center

In today's society, families are busy. Mom and dad are busy. The kids are busy. Everyone has different commitments at school, work, church, and outside activities, planned and unplanned, which pulls them in different directions throughout the day. It is often that family members do not cross paths: one person leaves before the other gets home. The arriving person would ideally like to have some type of explanation to note where the person who has just left has gone and when they will return.

In the DC world, a lightweight, unobtrusive means for family members to quickly and efficiently leave an outgoing message will be possible. For example, a DC message center could be available by the door(s) the family most frequently uses to enter and exit the home. The few seconds it may take one to remember where the keys are or to check one's appearance in the hallway mirror [148], would be all the time it would take to record a audio/video etc. message to a parent, spouse, or kids. Equally quick and lightweight, would be the method for the arriving person to check for messages from a particular family member or all messages [1].

3.4.2 Basketball Camp

Summer vacation is usually the time when kids get the opportunity to experience and participate in events such as church or sports camps, unaccompanied by other family members such as their siblings or parents. Parents strive to schedule novel activities that fit the child's particular interests, in keeping with the family's calendar and budget. While parents gladly pay for their kids to attend summer camps, most do not have time to attend them for any length of time to observe the camp experience of the camper, to see if they liked it, if they had fun, if they learned anything, etc. Campers themselves may be so busy participating in the activities, they may not have the time or the opportunity to sit back, soak in, and enjoy the details they wish to keep for later review (practice this neat skill I just learned) or memory-safekeeping.

My oldest son recently attended a four-morning basketball day camp at the local university in town. Being a big fan of basketball, I decided to stay to learn a little about the game and to see how they were teaching the kids. While observing the fundamental skills, competitive drills, and scrimmage games, I noticed the camp staff would have more time to spend with the kids if some of their information needs of running the sports camp could be taken care of with the help of DCs of the future. In addition, the traditional souvenir camp t-shirt [186] could be transformed into a wearable DC scrapbook. Using DCs, the child could capture their individual camp experience in a lightweight manner while attending and participating in camp activities, resulting in a camp t-shirt that will be irreplaceable in value at the end of the week.

3.4.3 Interactive Maps

A useful application for a DC that is paper-thin and can be rolled up for easy storage and transport is a map. In the third installment of the Harry Potter book series, Harry owns a map that was passed down to him by his father. It is not quite an everyday map. When the Marauder's Map is opened, you can see every person's current location at the Hogwart School represented by "tiny ink dots…each labeled with a name in minuscule writing". As each person moves about their environment, the "labeled dot", which represents him, also moves on the map to track their current location. A closer view of the map shows what the person is doing, for example "pacing" in the study [170].

A traditional everyday wall map could also be a useful DC application. Imagine planning a road trip for a family vacation. The destination may be one that you have been to before, so alternate routes should be considered for variety and the chance to go by new places. For example, when tracing the path from the start to the finish, a small "dust" trail might be left behind to track where your finger has passed on the map [117]. Then, when you step back to ponder the idea, your eyes and mind have a place to focus. Another example is to specify the start and destination, and let the map find and display the possible routes for you. Then you may want to "disable" certain paths if they are uninteresting or too out of the way for you to consider for this particular trip.

3.4.4 The Information Highway

While traveling along a highway, be it along a stretch where there is not much traffic, or in the middle of a busy metroplex, one cannot help but notice all the signs available for information. These include road signs to help you get to your destination, advertising billboards, restaurant and gas station signs, and the retail businesses situated in prime locations for this particular purpose. Each sign is basically composed of either static text, graphics and/or images, although some may include scrolling LED messages. The message must be succinct and to the point to be grasped in its entirety by one-time viewers. However, if it is a road traveled often, one would have multiple opportunities to “get the message”.

Billboards. Recently, as a passenger in a car, a sign along a busy highway caught my attention. It said, “We do for grocery stores what color did for television”. The graphic was a single ravioli with three vertical stripes (my guess) of the colors of the Italian flag. I think it was set against an old model television set. Unfortunately, I did not catch which grocery store the sign belonged to. Afterwards, I was not able to find it using a web search using parts of the slogan as keywords.

In the future world of DCs, every sign can potentially be a DC. While driving by, motorists (or perhaps preferably their passengers, for safety’s sake) should be able to “point and click” to specify either (1) “bookmark” this “link” for later reference or when I have time to review it (after reaching travel destination) or (2) for reading instantly – “I need the information now”. The DC world should allow everyone to instantaneously decide whether information they are literally faced with is important or interesting enough to be captured.

Restaurant Signs. Sign owners would make the public information available for “downloading”. The content may be similar to the type of content they publish now on their web sites. For example, a McDonald’s restaurant sign may offer the nutritional content of their fast food menu items. Due to competition between restaurant chains, their menu may change more frequently than one patronizes the establishment. The Nutrition Facts web page has ingredients, food exchanges [129], food allergen and sensitivity information for popular menu items, for those people who are watching what they eat for a particular reason.

Train Station. A recent family activity included a one-hour ride on the Tarantula train [65] from the Fort Worth Stockyards to the Trinity River and back. The train makes this run several times per day, and has another 1 1/2 hour each-way route to Grapevine and back. The ticket salesperson is the same person as the train announcer on board, and is only in the ticket booth when the train is actually sitting at the Stockyard Station. It would be very convenient if one could "point and click" at the Station sign to receive all the information listed on the brochure for the train schedule and ticket prices [66]. It happened that the Stockyard Information Center was just around the corner, so we were able to pick up a brochure there, having missed the last train by an hour or so the previous day.

Street Signs. A final example involves the residential community phone directory. Originally, Elkins Lake was a private country club residential community. It has since been added to the City of Huntsville limits. Every year, the community association still prints the Elkins Lake phone directory. It lists residents in the traditional "by last name" manner. The last two years, they have offered a supplemental book that lists residents by street address. Thus, if you are driving or walking down a street, you can determine every household of every house you pass. In the DC world, each street sign could have the information stored, such that a simple "point and click" at the sign would give you the same information.

Perhaps security issues on allowing the general public access to information so easily should also be addressed, although this information is readily available today via the Internet [5]. In addition, Elkins Lake homes [46] and lots [47] for sale are listed on the local real estate company website. This is another example of helpful information that could also be made accessible via street signs to people driving around the neighborhood looking for a new home.

3.4.5 Dynamic Photo Collages

By the time extended family members such as grandparents and great-grandparents reach their older years, they often have "everything" and gifts for birthdays, anniversaries, and holidays such as Mother's Day, Father's Day and Grandparent's Day, need to be more creative, meaningful, and "from the heart". Or perhaps the family members who live out-of-town are elderly, or are in poor health, or recuperating from a serious illness or hospital stay. At times like these, being there is the best thing. However, since that is not always possible, personalized gifts that provide a message that you care are always appreciated and can make both parties feel better.

Photos are a great example of a personal gift. However, once mailed and placed in a photo album or frame, they may be soon forgotten and remain un-viewed for a long period of time, until they are unexpectedly discovered later -- during a search for another photo, or because you are purposefully looking at pictures. With the advent of DCs, a traditional-looking picture frame can actually be a computer displaying photos in unusual and innovative ways, capturing the viewer's attention unlike any way it had before.

The DC picture frame can be of any size and hung anywhere a frame is traditionally placed. The computer is manufactured into the frame itself [117], unseen by the viewer. The viewer simply enjoys the set of photos being dynamically displayed in unusual and ever-changing ways (collages [107], montages [4], fades, etc.) generated by the computer software. It may be that the viewer enjoys sitting in front of the frame to "watch" it like a television set at times. However, it may also be equally enjoyable to go about one's daily business and perhaps out of the corner of the eye, have your attention captured by a peripheral view of the content of the frame, as you happen to walk by [223, 97, 84]. Then of course, you might be compelled to stay and watch for a few more minutes.

4. A DISPLAY COMPUTER PROTOTYPE

Children can benefit from Display Computers. The wide variety of form factors available via DCs can provide lightweight information to guide and encourage them to perform daily routines on a regular basis. The emphasis is on providing calm technology that is empowering, motivating, and most of all, enjoyable to use. With the help of consistent visual cues, kids at a young age can practice simple activities, such as getting ready for bed in a timely manner, with minimal help (or reminders) from their parents.

Providing ambient media applications on single function, simple-to-operate Display Computers tailored to young users will be possible in the near future. By offering the DCs in form factors such as familiar toys or stuffed animals, children are more likely to have fewer problems “adopting” them as their own. Any additional functionality provided by DCs may seem like a bonus! However, we hope to demonstrate with our DC prototype that DCs can be utilized as a valuable support mechanism of everyday activities for even the youngest member of the family.

4.1 Prototype

nbaCub (**n**ightly **b**edtime **a**mbient **C**ues **u**tility **b**uddy) is a custom-made stuffed leopard cub [23]. The original toy (see Figure 1) belongs to a five-year-old girl’s older brother. She has adopted the cub and sleeps with him every night.

Figure 1. Original leopard cub.

In this Display Computer toy prototype, the "NBA 1" portion of the cub's shirt is replaced with a Palm Tungsten T3 handheld personal digital assistant (PDA) running Palm OS v. 5.2.1. The PDA, with built-in Bluetooth for wireless communication, has a 320x480 transflective TFT display supporting over 65,000 colors that can be rotated from portrait to landscape mode in an instant [147].

The DC prototype displays a lightweight visualization (no audio) of "time passing" in the forty-five minutes before the child's bedtime. There are several different ways of displaying time passage cues through ambient media, from "least ambient" to "most ambient". See Table 1.

Table 1. Lightweight ambient display media.

	lightweight display	**symbols/colors**	**description**
a	digital clock *concrete time*	numbers, hh:mm	8:00 – 8:45 pm, changes every 5 min.
b	clock *concrete time*	analog time	8:00 – 8:45 pm, changes every 5 min.
c	digital timer *concrete time*	numbers, hh:mm:ss	countdown 45:00:00 to 00:00:00, changes every 5 min.
d	dcWorld (pie chart) *ambient time passage*	circle, pie slices, round world image, black	start with round image of world; every 5 min. overlay black (“night”) pie slice; 9 slices total for 45 minutes, at 5 min. each
e	tic-tac-toe *ambient time passage*	rectangle board, sun, stars	start with all 9 suns; every 5 min. replace a sun image with a star image
f	to-do list *ambient routine*	task images	task cues displayed at the proper point in 45 minute bedtime routine (snack time, story time, change clothes, brush teeth, get into bed)
g	to-do list on pie chart *ambient routine with time passage*	circle, pie slices with task images, black	start with round circle with task images on pie slices in order of routine; overlay darker pie slice on top of image when the timeslice is up
h	to-do list on tic-tac-toe *ambient routine with time passage*	rectangle board, task images, stars	start with a to-do task in each of 9 squares; every 5 min. replace a task image with a star image (initial sun images denote “free time”)
i	to-do list surrounded by ambient time frame *ambient routine with time passage*	task images framed by time passage	task cues displayed at proper point in 45 minute bedtime routine; each image change results in change in “time remaining” frame surrounding the image

As shown in Table 1, the actual time (a), (b) and a countdown timer (c) are included as options of a more concrete visualization of time. A child may be curious as to the exact time remaining until bedtime once they have a firmer grasp on the concept of telling time with a traditional clock. Of course, the common bedroom alarm clock and kitchen timer are also available to provide this information.

The next two lightweight displays (d), (e) provide an ambient visualization of time passage. See Figures 2 and 3.

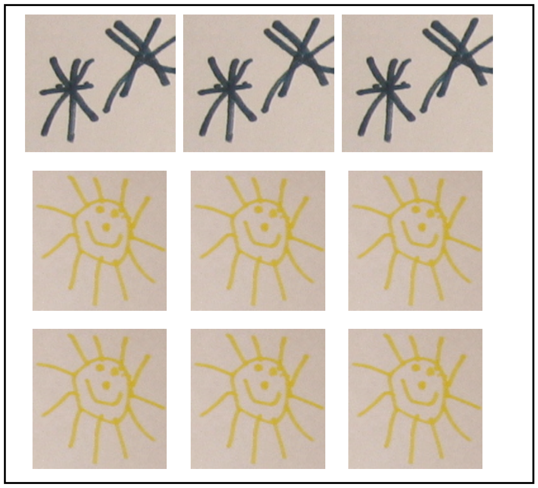


Figure 2. Prototype tic-tac-toe lightweight display of time passage. Fifteen minutes have passed, with 30 minutes to go until bedtime. Original artwork by child.

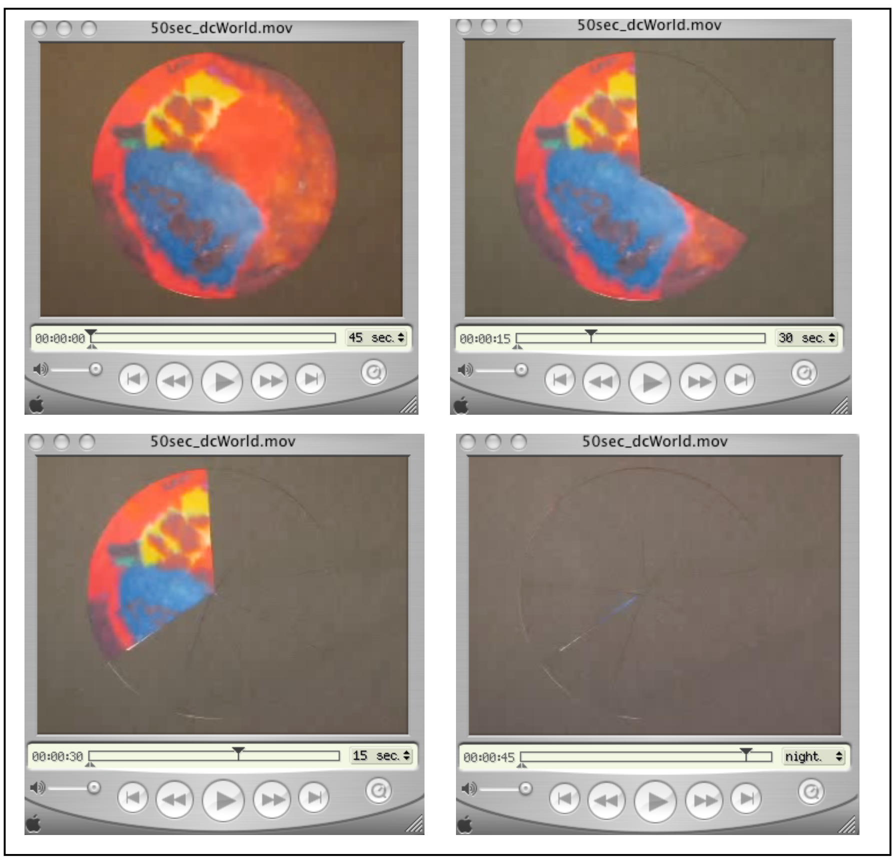


Figure 3. Prototype dcWorld lightweight display of time passage. Shown with the QuickTime Player on a laptop. Four chapters from top left: start of timer shows full image of entire "dcWorld"; after 15 min., 2/3rds of image remains; after 30 min., only 1/3 of image remains on display; final image is all dark…bedtime! Original artwork by child.

The sixth option (f) shows task image cues at the proper point in the 45-minute timeline: zebra cakes (snack time), Goodnight Moon book (story time), pajamas (change clothes), toothbrush and toothpaste (brush teeth), and favorite toy/pillow (get into bed).

The final three options are hybrid displays of both task and time passage. See Figures 4, 5, and 6. For example, option (h) is a combination of (e) and (f): instead of nine suns on the initial tic-tac-toe board, task images appear in each square, at the proper point in the timeline.

Depending on the individual child, a preference for a particular visualization may emerge, according to their interest in images, patterns, symbols, colors, or numbers. Or the child may simply enjoy the option of having a different display every night of the week.

The ambient media prototypes were developed using iLife ’04 software [93] for Mac OS X. Paper media, including scrapbook art and original artwork (see Figure 7), and everyday household items or toys, were photographed using a digital camera to create still images that were converted into movies viewable with the Kinoma Player [110] on the PDA as a lightweight display.

Figure 4. Prototype lightweight display of to-do list on pie chart. Four chapters from top left: start of timer shows full image of entire "pie"; after 15 min., 1/3rd of image turns black and white; after 30 min., only 1/3 of original color image remains on display; final image is all black and white… bedtime!

Figure 5. Prototype lightweight display of to-do list on tic-tac-toe. Task images are in each of 9 squares; every 5 minutes, replace a task image to show the time slice is up. Initial sun images denote "free time". Shown below: initial time (45 minutes); final display (at no time remaining).

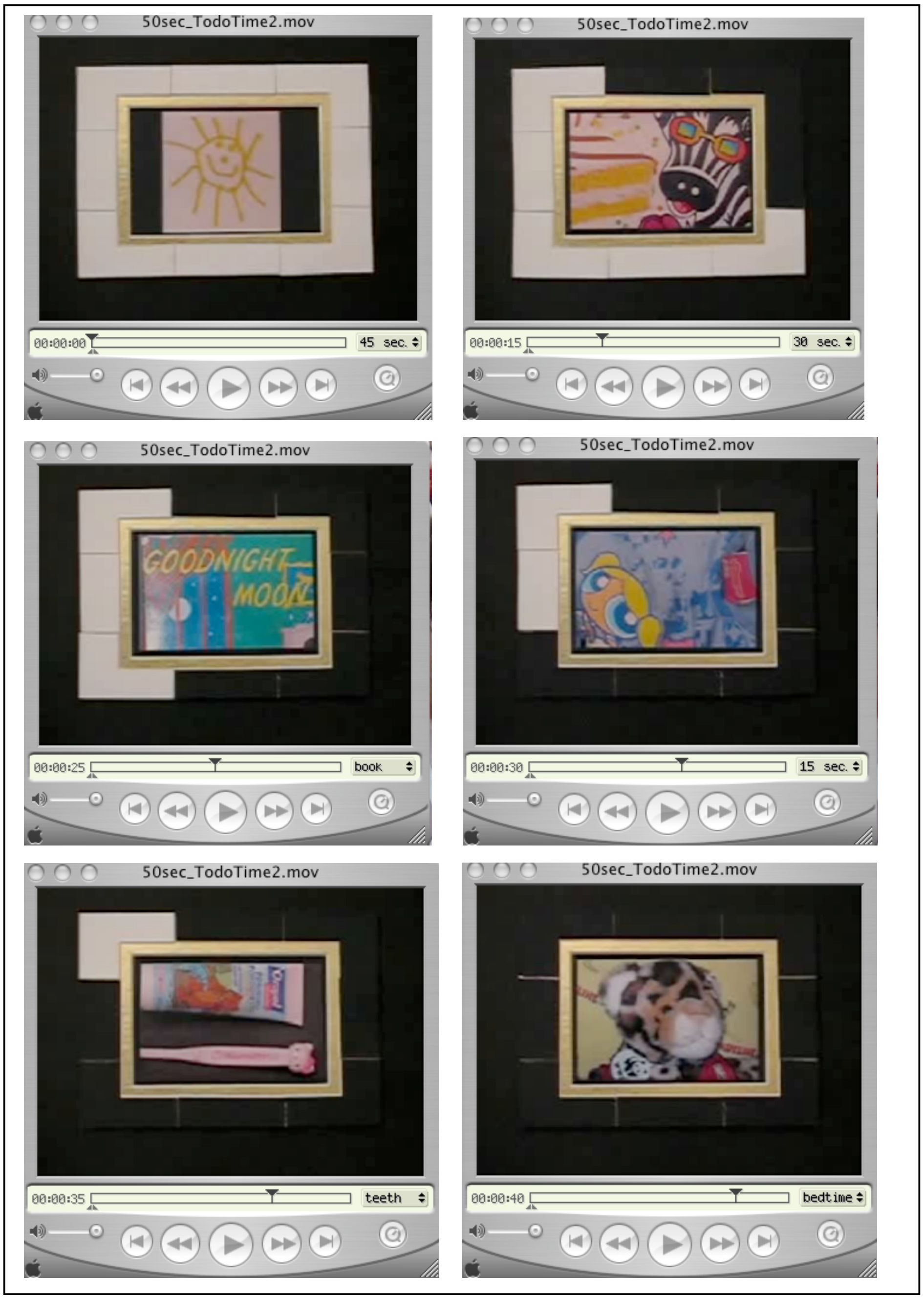


Figure 6. Prototype lightweight display of to-do list surrounded by time frame. Shown with the QuickTime player on a laptop. Task cues displayed at proper point in 45-minute bedtime routine. Each image change results in change of "time remaining" frame surrounding task cues. From left-to-right, top-to-bottom: sun images ("free time"), zebra cakes (snack time), book (story time), pajamas (change clothes), toothbrush (brush teeth), and pillow with favorite toy (get into bed). Sun image is from original artwork by a child.

Figure 7. Original artwork of child from which dcWorld image was taken.

Chapters (such as those found on DVD movies) defined at 45, 30, and 15 minutes add a level of interaction and choice for the start length of the lightweight display. Slider bars or chapters can be used to add or subtract minutes at any time during the actual display. The last chapter for all movies is the “night” chapter, and lasts for 5 minutes, making each full-length display a total of 50 minutes long.

The affordances of the native PDA input mechanisms are available for interaction on the mobile DC toy prototype. More specifically, all four hardware buttons on the PDA are programmed to automatically open the media player application. The PDA display is sensitive to touch via stylus (or small fingers) for additional input capabilities.

Special considerations were taken when embedding the PDA into the leopard cub DC toy prototype. The PDA itself must be secure enough to be mobile and “safe” during a child’s daily use, including expected levels of “wear and tear”. An additional requirement is that the PDA be easily retrievable from the DC form factor. Events such as recharging the battery, syncing the PDA with the “home” computer for transfer of ambient display media, and removal of the peripheral memory card are necessary on a regular basis.

4.2 Testing

A field study was chosen to test the usability of the nbaCub in the natural home setting. The child was given access to the nbaCub DC toy prototype in his home environment. A lightweight information display appeared on the nbaCub's shirt each evening before bedtime. The child then participated in a Test by Design activity to design and direct a lightweight display of a morning routine. This visualization combined both concepts of "time passage" and "routines" (to-do list task images) and was used for the lightweight display in the next phase. Final testing used an ambient media display that only visualized time passage. One goal of this study is to "observe process or technology in situ, disturbing the system we observe as little as possible" [8]. Thus testing was informal in procedure and observation and was conducted by the child's parent in their home over a period of 10 consecutive weeks. See Section 5; Appendices A and B.

5. CHILD'S PLAY: A FIELD STUDY

The nbaCub prototype illustrates a sample application of how Display Computers can be useful in the everyday environment of the home of the future. Embedding a computer into a toy, such that the display is the only visible portion, presents many opportunities for seamless and non-traditional uses of computing technology for our youngest user community.

5.1 Purpose

The purpose of the study was to observe and evaluate the use of the DC prototype as a novel and practical toy-and-tool-in-one. With nbaCub, we are providing lightweight, ambient information to kindergarten-aged children through a familiar "buddy" willing to accompany them as they go about performing the necessary daily routines of preparing for bed (evening routine), and preparing to go to school (morning routine).

5.2 Hypothesis

It is our prediction that a young child can learn, practice and begin to understand abstract concepts such as time and routines with the help of a personal DC toy. Visual cues presented step-by-step in real-time, can help with the visualization and understanding of time passage and the "to-do list" required to perform routine activities. A deeper understanding of the child's progress towards learning abstract concepts of time passage and routines will be gained through a "Test by Design" activity where the child is the primary designer or director of an everyday routine. By the end of the study, we believe the child will be able to generalize these concepts to other everyday routine activities, thereby only requiring the nbaCub to help out with time visualization (no task list).

5.3 Research Design

A field study was conducted to test the usability of the nbaCub in the natural home setting. The goal of this research strategy is to “observe process or technology in situ, disturbing the system we observe as little as possible” [8].

5.3.1 Required Materials

5.3.1.1 nbaCub

The personalized nature of the nbaCub to the target user (child subject) is of utmost importance to this research study. A form factor (stuffed animal, clothing, and accessories) customized to the user’s preferences will be used as the Display Computer toy prototype. This necessitates fabricating a new toy that differs from the original leopard cub for use as the Display Computer prototype in the field study. In addition, the ambient media display(s) will be personalized with both visual images and a bedtime routine that is familiar and meaningful to the young user. The middle of the shirt of the new DC toy prototype will be replaced with a Palm Tungsten T3 handheld personal digital assistant (PDA) running Palm OS v. 5.2.1. The PDA’s 320x480 transflective TFT display will serve as the “display” in portrait mode.

5.3.1.2 Ambient Media

The DC prototype will show a lightweight visualization (no audio) of “time passing” in the forty-five minutes before the child’s bedtime. Several different methods exist for displaying time passage cues through ambient media, from “least ambient” to “most ambient”. In this study, the two lightweight displays (a) and (b) from Table 1 will be used. See Table 2. While (a) is a hybrid display of both task and time passage, (b) shows time passage only. Note that option (b) (see Figure 3) is more general than (a) (see Figure 4). Option (c) will be a visualization directed and designed by the subject during the study and used in the final two phases.

Table 2. Lightweight ambient display media for field study.

	lightweight display	symbols/colors	description
a	**to-do list on pie chart** ***ambient nighttime routine with time passage***	**circle, pie slices with task images black**	**start with round circle with task images on pie slices in order of routine; overlay darker pie slice on top of image when the timeslice is up**
b	**dcWorld (pie chart)** ***ambient time passage***	**circle, pie slices, round world image black**	**start with round image of world; every 5 min. overlay black ("night") pie slice; 9 slices total for 45 minutes, at 5 min. each**
c	***ambient morning routine with time passage***		*To be designed by subject during Phase 2 of study.*

5.3.1.3 Interaction

Each of the four hardware buttons on the PDA will be set to automatically open the Kinoma media player application. The PDA display is sensitive to touch via stylus or small fingers for input capabilities. *Chapters* (such as those found on DVD movies) defined at 45, 30, and 15 minutes will add a level of interaction and choice for the start length of the lightweight display. The final chapter lasts for 5 minutes, making each full-length display a total of 50 minutes long.

The PDA will be secured in the toy to be mobile and "safe" during a child's daily use, including expected levels of "wear and tear". The PDA must be easily retrievable from the DC form factor by an adult, however. Events such as recharging the battery, syncing the PDA with the "home" computer for transfer of ambient display media, and removal of the peripheral memory card will be required on a regular basis.

5.3.1.4 Fabrication

The ambient media designed by the subject during the study will be made into a movie by the investigator using iLife '04 software for Mac OS X. The subject will design or specify which personal paper media (including scrapbook art and original artwork) and/or everyday personal items or toys are representative of morning routine tasks.

Photographs taken with a digital camera will be used as still images in a movie viewable on the Kinoma Player application using the PDA. The subject will direct the order and timing of the task images to complete the movie specification.

5.3.2 Required Personnel

One child subject will be required to carry out the study. Because the study will take place in the subject's home environment, the mother of the child will take part in the study as a data gatherer to observe and evaluate the child, and act as a facilitator during design sessions. Regular contact between the parent data gatherer and investigator during the course of the study will be required.

5.3.2.1 Subject

Druin discusses four roles children can have in the design and development of "new technology": user, tester, informant, and design partner [43]. The child participating in the ethnographic study of this prototype will play two of these roles: user and tester. In this study, our child does not fit the roles of informant and design partner as described by Druin, because he does not actively take part in the research or the design of the nbaCub prototype from the beginning. However, we have identified a new role the child will play in the "Test by Design" activity, that of primary designer or director.

Child as User. In observing the role of the child as a *user* before and after the novel form factor and ambient displays ("new technology") are introduced, we hope to understand what effect they have had on his understanding of time and routines ("learning experience").

Child as Tester. Using an "initial" prototype that has already been designed and created by adults, places the child in the role of a *tester*. Here again, simple observation, along with simple questions for "direct feedback", should help us to understand what impact the new technology has had on the child tester.

Child as Primary Designer/Director. After the initial usability study has been completed, we will have the child "direct" his own personal ambient media display for use on the nbaCub bedtime buddy. An example of a routine that would be very similar in concept to the bedtime routine but require a different set of visual cues and timeline, would be a morning routine to help him get ready for school. As the *primary designer* or *director* (as opposed to equal design partner in participatory design [43, 156] session(s)), he will have to express his concept of time in order to design prototypes of his ideas. The ambient media content could be personalized with his choice of original artwork or favorite belongings found around his home.

5.3.2.2 Data Gatherer

The "data gatherer" role is flexible and can be filled by one or many adults, namely: a parent, ethnographer, or investigator. In this study, the mother of the child will play this role. Having an outsider (ethnographer or investigator) in the household for the extended time period required by the study would most likely be too disruptive. It is important that consistent documentation of all observations and evaluations are kept. A workbook with all necessary forms will be provided.

Parent as Designer. Prior to the 10-week field study with the child subject, the parent and the investigator will work together to design a custom nbaCub Display Computer prototype specifically personalized to the child subject. Thus, in Phase 0, the parent is the primary designer and director, while the investigator is the facilitator and fabricator. Note this exercise will be repeated during the Phase 2 Test by Design sessions, where the parent will become facilitator, with the child being the primary designer and director.

Data Gatherer as Observer. During the entire study, a daily log of the time the child started getting ready for bed, the actual bedtime, any use of chapters, and additional free-form notes of any unsolicited comments the child makes pertaining to their access or use of the nbaCub and the lightweight information displays should be recorded by the parent data gatherer.

Data Gatherer as Evaluator. Each phase is divided into pre-testing, testing, and post-testing. The pre- and post-tests should provide a measure of the before and after knowledge and understanding of the abstract concepts of "time passage" and "routine" by the child. For example, during pre-testing the parent data gatherer might ask a simple list of open-ended questions about getting ready for bed.

Data Gatherer as Facilitator. The parent data gatherer taking part in the "Test by Design" activity and design sessions will fill the role of design "facilitator". Note that while it would be desirable to complete the design in one session, it may be necessary to have multiple sessions to finish the specifications for a prototype. Because the child is the primary designer, he should be the person to decide when the design is "finished". In addition, it may be the case that during usability testing of the nbaCub with the new routine, the child as the primary designer/director/user/tester may come to realize the design is not complete and wish to modify the design. In such a scenario, the field study should be flexible enough to allow for iterative design sessions that can produce multiple, rapid prototypes of ambient media displays undergoing the complete cycle of design, fabrication, and usability testing.

5.3.2.3 Investigator

The investigator will play the role of "producer" of the actual ambient media, and "fabricator" of the resulting prototype into a lightweight display viewable on the nbaCub for actual use in support of the new routine.

5.3.3 Methodology

Because the personalized nature of the nbaCub to the target user (child subject) is of utmost importance to this research study, a form factor that differs from the leopard cub will be used as the Display Computer toy prototype. Thus, in Phase 0, prior to the 10-week field study with the child subject, the parent and the investigator will work together to design a custom nbaCub Display Computer prototype specifically personalized to the child subject. See Table 3.

Table 3. Overview of Phase 0 field study.

Testing	Role of Child	Pre-Test	Test Activity	Post-Test
Phase 0a	target user	N/A	investigator and parent work together to design personalized nbaCub and ambient media display (similar to prototype (a)) for the child subject's bedtime routine	N/A
Phase 0b	N/A	N/A	investigator fabricates personalized ambient media display for R1	N/A

The overall design of the ten-week field study will involve four phases. See Table 4. The testing will be informal in procedure and observation. The child will be given access to the nbaCub DC toy prototype in his home environment. A lightweight information display will appear on the nbaCub's shirt each evening before bedtime. Two lightweight display types from Table 2 will be used during testing. The visualization (a) combines both concepts of "time passage" and "routines" (to-do list task images) and will be used for the lightweight display in Phase 1, and as the model for Phases 2 and 3. Phase 4 will use an ambient media display that only visualizes time passage (b).

Table 4. Methodology of 10-week DC prototype field study.

Testing	Role of Child	Pre-Test	Test Activity	Post-Test
Phase 1	user tester	concepts of time passage and bedtime routine (R1)	child uses nbaCub to support bedtime routine (R1); ambient media display (a)	understanding, learning of time passage and bedtime routine (R1); evaluation activities
Phase 2a	designer director	concepts of time passage and morning routine (R2)	*design session(s) of new ambient media display(c) for new morning routine (R2): child as designer/director; adult as facilitator*	N/A
Phase 2b	N/A	N/A	*adult as producer/fabricator of ambient media application designed by child (R2)*	N/A
Phase 3	designer director user tester	N/A	*child uses nbaCub to support new morning routine (R2) he designed/directed (c) [based on ambient media display (a)]*	understanding, learning of time passage and morning routine (R2); evaluation activities
			activities in Phases 2a, 2b, 3 (prior to Post-Test) may be repeated if child desires	
Phase 4	user tester	N/A	child uses nbaCub to support R1, R2; ambient media display of time passage only (b); no task image to-do list cues;	understanding, learning of time passage; bedtime (R1) and morning routine (R2); evaluation activities

5.3.3.1 Evaluation

Each phase is divided into pre-testing, test activity, and post-testing where applicable. The pre- and post-tests should provide a measure of the before and after knowledge and understanding of the abstract concepts of “time passage” and “routine” by the child. For example, pre-testing in Phase 1 might include a simple list of open-ended questions about getting ready for bed. Possible questions include:

(1) How do you know when it is time to get ready for bed?
(2) How long does it take for you to get ready for bed?

(3) What do you need to do to get ready for bed?
(4) How do you know when it is time to get into bed?

The same set of questions will be asked in the post-testing period. It is expected that the answers to the post-testing questions will be in more detail than before testing. An additional list of questions will be administered in each post-test period. These questions will be geared to finding out what the subject thought about the nbaCub, and if and how nbaCub helped them in getting ready for bed.

During the entire informal evaluation period, a daily log of the time the child started getting ready for bed, the actual bedtime, any use of chapters, and additional free-form notes of any unsolicited comments the child makes pertaining to their access or use of the nbaCub and the lightweight information displays will be recorded in the form of handwritten documentation.

Of primary interest, is whether the child's understanding of the two abstract concepts (passage of time, routine) improved after using the nbaCub DC prototype and ambient media application. Thus, in addition to the questions and logs, an evaluation activity to take place in the post-test period will consist of asking the child simple questions about time passage based on scenes taken from the lightweight displays, or asking him to demonstrate simple tasks such as ordering of the to-do list (bedtime routine tasks) using flashcards illustrated with ambient media elements.

5.3.3.2 Test by Design

To provide a deeper understanding of the child's progress towards learning of the abstract concepts of time passage and routines in Phase 1, Phase 2a will entail a "Test by Design" activity where the child is the primary designer or director of a similar, but different everyday routine. Phase 2b concludes with the actual fabrication of a prototype movie that can be viewed on the nbaCub DC prototype. Phase 3 is basically a repeat of

Phase 1, the only difference being the everyday routine that is being used and tested (morning routine instead of bedtime routine), and the fact that a pre-test is not necessary, having been performed already in Phase 2a. It is expected that the child will show better understanding of the morning routine and time passage in the post-test results of Phase 3, by simple virtue that he was the primary designer of the ambient media display. Note the activities of Phase 2a, 2b, and 3 may be repeated several times if the "child as primary designer" wishes (he believes and the adult agrees it may not be "finished"). Thus, the child may participate in one or more design cycles.

5.3.3.3 Final Testing

The final phase, Phase 4, will repeat the Phase 3 testing with the nbaCub, with two differences. The nbaCub will be used every morning and evening, and the ambient display will no longer show visualizations of the to-do list, but offer only the lightweight passage of time. We believe that after Phases 1, 2, and 3, the child will have a firm enough grasp on the concept of routine and the specific bedtime and morning routines expected of him, that he will be ready to perform his everyday routine activities with the nbaCub buddy showing only ambient displays of time passage (b).

5.4 Research Procedures

See Appendix A for detailed Research Procedures. Organized by Phases, starting with Phase 0a, Phase 0b, Phase 1, etc., each phase includes a list of Required Materials, Required Personnel and Roles, Sample Test Plan Schedule, and checklist of Research Procedures.

5.5 Assessment Instruments

See Appendix B for detailed report of the Assessment Instruments used in the field study. Included are a Sample Test Plan for Phases 1-4, Sample Calendars by TestID and DocumentationID, and explanation and examples of all Documentation Forms to be used by the Data Gatherer.

The four types of documentation forms used as assessment instruments include observation logs, questionnaires, usability testing, and evaluation activities.

Observation Logs. The child subject will be observed each day of the field study by at least one adult (his or her parent in the role of data gatherer). The purpose is to get an idea of what the subject's daily routines in question are before, during and after the use of the nbaCub Display Computer prototype. Thus, for Phases 1 and 4, an observation log should be filled out during the bedtime routine. For Phases 2, 3, and 4, an observation log should be filled out during the morning routine.

Questionnaires. The purpose of the questionnaires is to provide a pre- and post-test measure of the before and after knowledge and understanding of the abstract concepts of "time passage" and "routine" by the child, before and following the use of the nbaCub Display Computer prototype.

Usability Testing. Usability testing refers to the actual testing activity in each phase of the study. For example, in Phases 1, 3, and 4, the actual testing activity is having the subject "use" the nbaCub to support his daily routine(s). In Phase 2a, the testing activity is the Test by Design session(s) where the subject is the primary designer or director. In Phase 2b, the primary activity is the fabrication of the design resulting from Phase 2a. Phases 0a and 0b are similar to Phase 2, except the parent plays the primary designer and director roles, while the child subject has no role yet.

Evaluation Activities. The purpose of the evaluation activity is to provide a post-test measure of the subject's understanding of the two abstract concepts (passage of time, routine) following the use of the nbaCub DC prototype and ambient media application(s).

For each phase of the study, a workbook of documentation forms was provided to the parent/data gatherer as an assessment instrument to record the research study observations on a daily basis. The sample test plan and calendars served as a guide or table of contents to the appropriate forms to use for each day of the study (by phase in sequential order by week and day of study).

6. SUMMARY OF RESULTS

Before the field study of the DC prototype could be conducted, approval of the human subject protocol was needed from the Institutional Review Board (IRB) at Texas A&M University. Because the proposed study included a kindergarten-aged child, a full review of the 84-page protocol took place. Child subjects under the age of 7 are not required to assent to the study. The parent (as data gatherer subject) signed the Consent Form document approved by the IRB on behalf of herself and her five-year old child. See Appendix C.

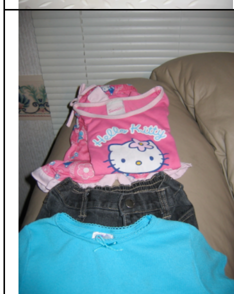
6.1 Phase 0

Phase 0 was conducted prior to the commencement of the 10-week field study in the subject's home environment. One goal of Phase 0a was to obtain the required materials to fabricate a personalized ambient media display for the subject's bedtime routine. The other goal was to select the form factor to be used as the field study's nbaCub DC toy prototype. For Phase 0b, the investigator used the materials from Phase 0a to fabricate the nbaCub DC toy prototype and the ambient media display to be used in the field study.

6.1.1 Phase 0a

The investigator (as co-designer) provided the parent (as primary designer) with a poster containing illustrations of possible form factors. The parent immediately spotted a pink pig she predicted would be her child's favorite. Upon viewing the poster, the child confirmed it was indeed the stuffed animal of choice. The parent and investigator made arrangements to meet at the commercial store [23]. The investigator purchased one pig form factor un-stuffed, and one pig stuffed animal. The parent undertook the process of supervising the making of the stuffed pig and its birth certificate (named "Miss Piggy").

Table 5. Bedtime routine fabricated as ambient media display for Phase 1 testing.

	Image/ Bedtime Activity	Length	Time Remaining
	Shrek toothpaste and bath bubbles/ Take bath, brush teeth	15 minutes	45 minutes
	PJ's, school clothes/ Put on PJ's, lay out school clothes for the next day	10 minutes	30 minutes
	Kid Cuisine/ Pick lunch	5 minutes	20 minutes
	Leap Pad/ Read book	10 minutes	15 minutes
	Pillow/ Get into bed	5 minutes	5 minutes
	No image/ Tuck into bed		0 minutes

In addition the parent chose clothing (LeCat outfit with pink shirt, black skirt, and black handbag) and accessories (pink underwear and a pair of pink shoes) for Miss Piggy, which were purchased in duplicate by the investigator. The investigator took the un-stuffed pig form factor for use in Phase 0b. The investigator also took the stuffed animal pig with the plan to return it to the parent later. This replica of the DC toy (sans display computer) used during the field study would be given to the subject at the end of the study.

Upon leaving the store, the investigator and parent met at the home of the subject. The subject was not present. Discussion between the investigator (as co-designer and fabricator) and parent (as primary designer and director) of the family and subject's evening habits resulted in a design for a 45-minute bedtime routine to be used in testing. In addition, the investigator took digital photographs of personal items belonging to the child to represent each defined bedtime activity. See Table 5.

Figure 8. nbaCub DC prototype fabricated for field study.

6.1.2 Phase 0b

In Phase 0b, the investigator used the materials gathered in Phase 0a to: (1) fabricate a new ambient media display personalized to the child's bedtime routine; (2) update assessment instruments to be used in testing; and (3) collaborate with a professional seamstress to modify the un-stuffed pig form factor and the pink LeCat shirt such that together they would securely hold the PDA in place during testing. Upon completion of (3) the pig form factor was stuffed and dressed at the commercial store to create the nbaCub Display Computer toy prototype used in the field study. See Figure 8.

6.1.3 Discussion

Phase 0 went very well. Between the parent, investigator, and professional seamstress, there were no problems fabricating the new nbaCub or ambient media display. See Figure 9. The nbaCub, PDA, and Phase 1 Workbook were turned over to the parent for an on-schedule start to the 10-week field study with the child subject.

Figure 9. Lightweight ambient media display of full bedtime routine.

6.2 Phase 1

The 10-week field study commenced in the subject's home environment with Phase 1. This phase lasted three calendar weeks, with weekends off. The first week (Week 1) consisted of pre-testing: five days of observation of the subject's bedtime routine without the nbaCub Display Computer prototype, and a pre-test questionnaire. The second two weeks (Week 2, Week 3) included daily observation of the child's bedtime routine with the availability of the nbaCub as a bedtime buddy; the lightweight ambient media display developed in Phase 0 was available to support the child during the bedtime routine. Phase 1 concluded with post-testing: two questionnaires and two evaluation activities. A Phase 1 Workbook was provided to the parent data gatherer to serve as a detailed guide and place to record all observations and testing activities.

6.2.1 Pre-Testing

Week 1 pre-testing daily observation logs showed the subject spent more than 45 minutes each evening preparing for bed. The shortest time was 53 minutes; the longest time was 1 hour 15 minutes. The bedtime routine itself was varied, along with the order and time taken for bedtime activities. Additional activities not discussed in Phase 0 included: fixing hair, cleaning room, watching TV, and multiple tuck-ins/lights out situations. The Phase 1 pre-test questionnaire given by the parent at the end of Week 1 showed the subject relied on her parents to know when it was time to get ready for bed and go to bed. Her quantification of the time to get ready for bed was, "*I think it takes like 10 minutes.*" In answering the question "What do you need to do to get ready for bed?" she listed the bedtime routine from Phase 0 in order, leaving out two items: picking out lunch and reading book.

6.2.2 Usability Testing

At the start of Week 2, the subject was given the nbaCub DC toy prototype ("Miss Piggy") by the parent. The subject had two comments about the new bedtime buddy: the first was the stuffed animal did not have the original outfit she had wanted (from the poster); and she also asked if she could sleep with her (the nbaCub bedtime buddy). The parent explained the lightweight ambient media display to the child by explaining the movie and making sure she understood every picture. Unfortunately, the battery of the PDA was low and needed charging on the first night it was to be used. The parent removed the PDA and charged it, and let the subject sleep with the nbaCub.

The remainder of the week showed mixed usage of the nbaCub. The parent selected the nbaCub three of the four days; the subject selected it herself on the third day. On two of the four days, the subject carried around the nbaCub "some" of the time, on one day "most" of the time. On one evening, she left the nbaCub sitting in one spot, returning to check the content of the display as she completed bedtime activities. One observation the parent recorded was "not sure what to do when time allotted on movie is too much time… just let <subject> use movie screen to guide her through her routine". The subject spent 48 minutes or less on her bedtime routine during Week 2. The nbaCub received two marks for being "somewhat helpful", one mark for being "very helpful", and one mark for "not helpful". On the "not helpful" Friday evening, the bedtime routine consisted of only twenty minutes: 17 minutes for bath/brushing teeth, and 3 minutes for laying out clothes for the next day's basketball game.

Week 3 of the field study was the second week of the usability study of the subject using her bedtime buddy with the ambient media display of her personalized bedtime routine. The nbaCub was used only the first three days of the week. The parent selected the nbaCub twice, the subject once; the time for bedtime routine was 44 minutes, 35 minutes, and 37 minutes, respectively; the nbaCub received three marks for being "somewhat helpful". On the third day, the parent noted "<Subject> brought nbaCub to me to start movie for her. We ask <subject> what does Piggy say she should be doing when she gets off-task." On the fourth day, the PDA battery was too low; and fifth day, a Friday, there was no school to get ready for the next day. Neither subject nor parent selected the nbaCub on the Friday evening. The Friday bedtime routine was similar to the previous week: a long bath, brushing teeth, laying out basketball clothes and water bottle for the next morning's game.

6.2.3 Post-Testing

Post-testing at the conclusion of Phase 1 included the same questionnaire used in pre-testing. The subject said it took her "*twenty minutes*" to get ready for bed; her routine was "*I need to brush my teeth and wash my face, take a bath, use Piggy, get my lunch, read, and then I go to bed.*" When asked, "How do you know when it is time to go to bed?" the subject answered, *"Piggy tells me because of her pictures. The picture of my pillow.*" A second questionnaire targeted the subject's opinion about the nbaCub. Question 1: "What did you like best about Miss Piggy?" Subject's answer: "*I like her clothes and how she looks and her purse. I like everything about her.*" Question 2: "Did she help you get ready for bed? How?" Subject's answer: "*Yes, she tells me what to do and what not to do first.*" Question 3: "If you would change any of the pictures, what would you change?" Subject's answer: "*I would change my bath picture – I would put the bubbles before the toothpaste because I take a bath before I brush my teeth.*" Question 4: "What are some other things Miss Piggy can help you with, other than getting ready for bed?" Subject's answer: *"I want her to help me wash my hands before I eat and when I come from outside, and after I go to the bathroom.*"

Additional post-testing took the form of two evaluation activities to evaluate the subject's understanding of time passage and her bedtime routine. In the first activity, she was given four flashcards of images taken from the ambient media display of the bedtime routine, one at a time. For each image, she was asked a question relating to either the time left in routine or what activity would be next. For the image that was totally black and white, she correctly answered there was no more time to get ready for bed. For the image that was entirely in color, she correctly answered she needed to still complete the whole routine, although she did not quantify time as a specific number. Her answer, "A lot. I still have time to do everything I'm supposed to do." For the second evaluation activity, she was given five flashcards, each depicting a bedtime activity. She was given the cards in the order of task 5, 1, 4, 3, 2, and correctly ordered them into 1, 2, 3, 4, 5 on the first try.

6.2.4 Discussion

Phase 1 of the DC prototype study showed positive results. During pre-testing, the shortest amount of time to prepare for bed was 53 minutes. For the two weeks of usability testing with the nbaCub, the longest time recorded for the bedtime routine was less than the 53 minutes at 48 minutes and 44 minutes, respectively. The nbaCub received only one "not helpful" rating out of the 7 days (out of 10 scheduled) the DC prototype was used by the subject. One explanation could be the Friday bedtime routine necessarily varied from the earlier days in the week because the following day was a Saturday, with no school to prepare for. In retrospect, the investigator should have prepared the test plan to coincide with a Sunday evening to Thursday evening weekly schedule.

The post-testing of Phase 1 provided interesting information. The subject's positive comments on liking everything about Miss Piggy and how she was helpful by telling her what to do and what not to do, showed the subject identified with Miss Piggy's DC form factor and ambient media display as one entity. She relied on the visual images of the ambient media display to carry out the bedtime routine activities and seemed to have adopted the nbaCub as a helpful buddy. In fact, she pointed out the small detail of a discrepancy between an image and her actual routine. The investigator photographed her Shrek toothpaste to the left of her Shrek bubble bath, when in her bedtime routine she actually took her bath before brushing her teeth. Surprisingly the subject requested, when asked, she would like to have Miss Piggy's help with a very necessary daily activity: hand-washing before eating, after being outside, and after using the restroom. In her eyes, the nbaCub could be a helpful companion with other tasks outside the timeframe of preparing for bed. The perfect completion of both evaluation activities on the first try showed the subject understands relative time passage as it relates to the order of the bedtime routine activities and is very familiar with the activities required to get ready for bed each evening.

6.3 Phase 2

Phase 2 was scheduled for three calendar weeks, with weekends off for the parent and subject. The parent was scheduled to log observations of the subject's morning routine (without the support of the nbaCub and lightweight display) for all three weeks. Phase 2a consisted of two weeks, Phase 2b one week. The single pre-test questionnaire was given at the beginning of Week 4. The second week (Week 5) was scheduled for the parent (as facilitator and data gatherer) and the subject (as primary designer or director) to work together to design a new morning routine. In Phase 2b (Week 6), the investigator was scheduled to fabricate the new morning routine designed in Phase 2a as an ambient media display. A Phase 2 Workbook was provided to the parent data gatherer to serve as a detailed guide and place to record all observations and field study activities.

6.3.1 Phase 2a

In the Phase 2 test plan, the parent was to observe and record the subject's morning routine for all three weeks. Of the 13 (out of 15) days observed, the time to get ready for the morning routine ranged from 15 minutes to 45 minutes. The comments logged for the shorter times included: "woke up late", "left early", "running late." The morning routine consistently contained 4 separate activities and a block of free time at the end.

On at least three occasions, the “wash face/brush teeth” was replaced by the “bath/brush teeth” morning activity.

6.3.1.1 Pre-Testing

At the end of the first week, a pre-test questionnaire was given. Question 1: “How do you know when it is time to get up in the morning?” Subject’s answer: “*Sometimes I wake up by myself and sometimes my parents wake me up.*” Question 2: “How long does it take you to get ready to leave the house in the morning?” Subject’s answer: “*I think about 10 minutes.*” Question 3: “What do you need to do to get ready to leave the house in the morning?” Subject’s answer: “*I need to get my school clothes on, get my bed clothes off. Then I get my hair done. Brush my teeth and wash my face. Get my backpack on.*” Question 4: “What do you need help with when you get ready in the morning?” Subject’s answer: “*I need help getting my hair done.*”

6.3.1.2 Extra Usability Testing

There was no usability testing on the test plan for Phase 2. The parent called the investigator to ask if it was OK to let the subject continue using the nbaCub to support her bedtime routine. The parent also offered to make duplicate copies of the observation log sheets in the Phase 2 Workbook, so records could be kept for both morning and bedtime activities. The investigator immediately agreed continuing use of the nbaCub would be fine. The Phase 2 Workbook showed the parent followed a Sunday to Thursday five-day week. Of the three weeks, the nbaCub was used 3 evenings in Week 4, 3 evenings in Week 5, and 2 evenings in Week 6 for a total of 8 of 15 evenings. Interestingly, the days of the week were consistent: Sunday, Monday, and Thursday for the first two weeks, and Sunday, Monday for the third week. For the six of the seven evenings the nbaCub was not used, there was an explanation recorded: “we were out late… she was tired and went straight to bed when we got home… <subject> and mommy were sick and not feeling good; we fell asleep before it was time to start Piggy… we went out of town, and did not get home until 10 p.m. she fell asleep in the car… <subject> did not select Piggy and I forgot to give it to her… we got home late." (Note: preparation to leave town for a family emergency may have been one reason the nbaCub was not used on the third Thursday with no explanation logged for non-use.)

The nbaCub was rated "somewhat helpful" on six of the eight days it was used by the subject, and "not helpful" on two days (Day 32 and Day 35). On the evening of Day 32, the subject carried the nbaCub bedtime buddy at the start of her 26-minute evening routine, and said, "*I don't need Piggy I know what to do.*" On the evening of Day 35, the subject said the same thing, "*I don't need Piggy I know what to do*", but was observed by the parent carrying the nbaCub around anyway. The parent wrote: "<Subject> carried Piggy around just to carry her." On this particular evening, the subject's bedtime routine took 59 minutes. For five of the other six evenings, the time range for the bedtime routine was consistently between 42 and 52 minutes. On the evening of Day 28, her bedtime activities took only 32 minutes. The parent explained, "<Subject> had to decide what to take for lunch. We did not have any lunchables/Kids Cuisines. Once I told <subject> it was time for her to start her routine she got Piggy."

The evening of Day 29 was the first time the subject showed interest in starting the ambient media display on the nbaCub Display Computer prototype by asking "*How do you start Piggy?*" On the evening of Day 36 of the study, the subject started the ambient media display for the first time without help, saying, "*I want to start Piggy.*" The parent observed, "I selected Piggy, <subject> started Piggy, but didn't use her."

6.3.1.3 Test by Design

According to the Phase 2 Workbook, on Day 31 of the study, the parent and subject designed a morning routine together. It took 45 minutes for the design activity according to the worksheet "Design Session Log, D2-2". The parent logged this comment on the subject's role in the design session: "When asked what all do you do to get ready for school, she ran down the activities. She does not have a sense of time."

Instead of describing specific activities of the design session itself on the worksheet, the parent listed the new morning routine. The newly defined morning routine should have been listed on a different worksheet titled “Test by Design Session Summary 1, A2b”. This worksheet was not filled out in the Phase 2 Workbook.

On the evening of Day 39, the parent contacted the investigator about a family emergency. The family was planning to leave to go out of town for a funeral the next day. Hurried arrangements were made for the investigator to have short access to the required materials for the new morning routine on Day 40. The parent returned the PDA (but not the nbaCub form factor or Phase 2 Workbook) and left a note among the materials regarding the specifics of the design of the new morning routine. Based on this information, the investigator took digital photographs of the borrowed subject’s personal items, before returning the items the same day. Because the television set in the subject’s home was not portable enough to be available for a photograph, the parent requested the investigator take any picture of a television screen to represent the morning routine activity of “free time”. See Table 6.

Table 6. Morning routine fabricated as ambient media display for Phase 3 testing.

	Image/ Morning Activity	Length	Time Remaining
	Thomas the Tank Backpack/ Put lunch kit with backpack	5 minutes	45 minutes
	Tub of hair things and hair brush/ Get hair fixed by mommy	10 minutes	40 minutes
	Towel and toothpaste/ Brush teeth, wash face	10 minutes	30 minutes
	School clothes/ Get dressed for school	5 minutes	20 minutes
	TV/ Free time	15 minutes	15 minutes
	No Image/ Leave for school		0 minutes

6.3.2 Phase 2b

The investigator used the materials from Phase 2a to fabricate an ambient media display of the subject's personal morning routine in Phase 2b. See Figure 10. Both the ambient media display for the new morning routine (for Phase 3 testing) and the ambient media display of time passage only (for Phase 4 testing, see Figure 3) were loaded onto a Secure Digital memory card external to the PDA. The ambient media display for the original bedtime routine was left in the PDA's main memory. In addition, assessment instruments to be used in Phases 3 and 4 were updated. As discussed with the parent in Phase 2a, worksheets were added to the Phase 3 Workbook so the subject could use the nbaCub both in the morning and the evening outside of the original test plan of usability testing in the mornings only.

The parent did not pick up the PDA (with the three different ambient media displays) and the Phase 3 and 4 Workbooks as scheduled on Day 43. The start of Phase 3 of the field study with the nbaCub and new morning routine was a day and a half behind schedule according to the original test plan. (Note: the testing schedule was not changed because of this; however, testing with the nbaCub for the two mornings was not possible.)

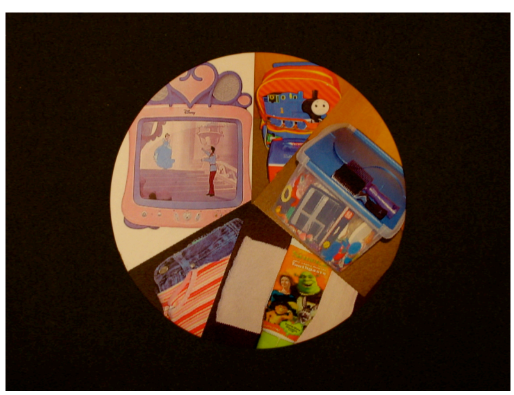


Figure 10. Lightweight ambient media display of full morning routine.

6.3.3 Discussion

It was a nice surprise the parent requested unscheduled continued use of the nbaCub to support the subject's evening routine even though it meant more data gathering responsibilities for the parent. The six days the nbaCub was actually used by the subject, the child was able to stay on schedule in preparing for bedtime. Both nights the subject said the nbaCub was not needed, the time for the bedtime routine was noticeably shorter and longer. All three nights the nbaCub was not used before going to bed coincided with three following mornings the subject needed to take a bath before school. The parent logged, "<Subject> did not do routine last night, so she had to bathe this morning." Like Phase 1, Friday evenings were not a choice day for the nbaCub and bedtime routine because the next day was not a school day. On Day 26, the parent observed, "Piggy's PDA needed to charge. Not sure how to check battery life. <Subject> has a b-ball game tomorrow, so her routine is somewhat different." Twenty-nine days into the 10-week field study, the subject expressed interest in learning how to start the ambient media display on the nbaCub DC prototype. And a week later, the subject took the initiative to start the display without help. Although the subject sometimes ignored the ambient display, the nbaCub continued the role of bedtime buddy and companion by being carried around.

The observations of the morning routine showed it was dependent on the subject's bedtime routine (did the subject take a bath?) and dependent on the parent's morning schedule ("woke up late… needed to leave early… stop for donuts"). The pre-test questionnaire showed the subject had a general idea of activities required to get ready for school in the morning. Again her answer of "10 minutes" to get ready showed she had no sense of time quantity itself.

In reviewing the Phase 2 Workbook, the "test by design" activity in which the parent (as facilitator) and subject (as primary designer) participated in together, did not seem to be as rigorous as the investigator would have hoped. The parent did not fill out the worksheets correctly, and not much information about the actual give-and-take of the design session can be gleaned from the actual documentation available. It was logged that the subject listed the morning routine activities in order. The comment that the subject did not have “a sense of time” seems to point to the parent assigning the specific time frame for each of the morning activities. There is no record of the subject selecting which personal belongings should be used to represent a particular morning activity.

In the planning phase of the field study, there had been discussion of scenarios for the Phase 2a design sessions that could ensure accurate procedures were followed and full documentation could be recorded. Options discussed included: having the investigator present, using a visual/audio recording device to log design sessions, having the design sessions in a location outside the home environment. Each of these conflicted directly with the desire to preserve the natural home setting of the field study, and disallow outside contact with the subject during the field study. For the stated goal of the study’s research strategy was to “observe process or technology in situ, disturbing the system we observe as little as possible” [8]. Nonetheless, because the Test By Design activity was a key element of the initial test plan, the investigator should have specifically scheduled a meeting with the parent to go over the “test by design” idea and procedures immediately prior to Phase 2a of the field study.

The unexpected family emergency brought Phase 2a to a hurried stop. Luckily there was time to transfer research materials (design materials and PDA) before the family left town. Without the confirmation of the Phase 2 Workbook contents (the workbook was not available), the investigator relied solely on the note left on Day 40 about the design of the new morning routine to fabricate the new morning ambient media display to be used in Phase 3 of testing. In retrospect, this was a huge misstep. In the note, the parent had listed the new morning routine activities in one column, with time in another column to the right. The investigator used this list as-is. The scheduled time for Phase 2b was drawing to a close, and the investigator had only three days (Days 40, 41, 42) to fabricate the new morning routine as an ambient media display. Only after the entire 10-week study was over would the investigator find the note should have been crosschecked with the Phase 2 Workbook before the morning routine was fabricated. Long story short, in Phase 3, the parent and subject discover the morning activities represented on the new morning ambient media display are not in the correct order. The parent did not contact the investigator explicitly to share this information. Only after the conclusion of the entire study did the investigator learn of this from reviewing the Workbooks.

At the immediate conclusion of Phase 2, the investigator erroneously felt this particular part of the field study had gone “OK”. Frankly, there were two undesirable outcomes that had occurred after review of Phase 2a with hindsight 20/20 vision. Regularly scheduled communication between the investigator and the parent would have helped ensure the parent understood the expectations of the test by design activity regarding design roles of the parent and subject, specific procedures, and documentation required. The lack of communication was compounded by the unexpected family emergency. In the rush to transfer required materials, the Phase 2 Workbook was not returned. There was also a sense on the investigator’s part of the need to stay on schedule. The ten-week field study was scheduled to end immediately before the start of Spring Break. Failure to stay on schedule would break the continuity of the field study due to travel plans of the family over the break. The lack of (the perception of enough) time and the failure to confirm the actual morning routine was correct turned out to be very costly, as an element central to the Phase 3 test plan was fabricated incorrectly.

6.4 Phase 3

The test plan for Phase 3 was similar to Phase 1 testing, with the difference of having the subject use the nbaCub and new ambient media display to support the daily morning routine instead of the evening bedtime routine. This phase was scheduled for two calendar weeks, with weekends off. No pre-testing was necessary in Phase 3. (The pre-testing for the morning routine was conducted in Phase 2a previously). Both weeks (Week 7, Week 8) included daily observation of the child's morning routine with the availability of the nbaCub as a morning buddy; the lightweight ambient media display fabricated in Phase 2b was available to support the child during the morning routine. Phase 3 concluded with post-testing: two questionnaires and two evaluation activities, designed similarly to Phase 1 post-testing instruments. A Phase 3 Workbook was provided to the parent data gatherer to serve as a detailed guide and place to record all observations and testing activities.

In Phase 2a, the parent requested to continue usability testing for the subject with the nbaCub in support of the bedtime routine for both Phases 2 and 3. In Phase 2b, the Phase 3 Workbook was modified to include additional worksheets for the evening observations. Results of the extra usability testing are reported next.

6.4.1 Extra Usability Testing

The nbaCub was not available to support the bedtime routine the first evening of Week 7 because the PDA was not in the parent's possession. However, the subject did ask about it, "*Where's my movie for Piggy*?" The next evening, the PDA was available, and the subject used the nbaCub DC toy prototype for the first time in 8 days. (The nbaCub was not used between Day 36 and Day 44.) Return of the nbaCub to the subject got rave reviews from the subject "*I LOVE PIGGY!*" and an observation from the parent "<Subject> carried Piggy more tonight that she ever has. She used the movie like it was her first time!" On Day 45, the subject started the ambient media display with help, but the battery was low on the PDA and the nbaCub could only be used for half the routine. The next evening, the subject "carried Piggy around except for to decide on lunch." Washing and styling of the subject's hair stretched the bedtime routine to over an hour. The time range for the bedtime routine for the other three evenings was between 26 and

42 minutes. The nbaCub was rated “somewhat helpful” for all four evenings it was used in Week 7.

Like Week 7, the subject used the nbaCub for 4 days out of 5 in Week 8. It was rated “somewhat helpful” for all four evenings. On Day 49, the subject was able to start the ambient media display without help after the parent chose the correct routine (choices were: bedtime, morning, or time-only). The parent made this entry on the subject’s comments: *“Mommy can I turn Piggy off since I know what to do after you finish with my hair?* (<Subject> learned how to take Piggy’s screen out.) *Mommy here is Piggy’s movie.*” Two days later, the subject said she didn’t need the nbaCub for the evening routine, “*I don’t need Piggy’s movie in*”. On this night, the bedtime routine stretched to 1 hour and 20 minutes, while the actual time ranged from 25 to 41 minutes on the other evenings.

6.4.2 Usability Testing

Records show the subject was anticipating the new ambient media display before it arrived, “*I thought you said <investigator> was going to make me a morning video.*” The morning of Day 45 was the first time the subject was able to use the nbaCub for her getting ready for school routine. The subject immediately noticed the discrepancy between the ambient display and her actual routine, “*Mommy look! This is not the right routine on the movie. It says to do backpack first, and I brush my teeth.* (We talked about giving movie back to <investigator> to change.) *I’ll just leave it.*” The parent added an observation, “<Subject> knows how to get Piggy to turn on, but she did not know which movie to choose.” It should be noted the subject did consistently use and follow the new morning routine illustrated on the ambient media display for both Week 7 and Week 8. For the 3 days the subject used the nbaCub in Week 7, the time for the morning routine was 35, 44, and 50 minutes. However, the amount of free time as the last morning task varied at 4, 10, and 14 minutes, respectively.

For Week 8, Daddy was out of town, necessitating a change of the normal routine. Mommy taking the subject to school required both the parent and subject to get up earlier each day. The total time for the morning routines were consistently between 40 minutes and 1 hour; with 10, 20, or 30 minutes of free time at the end. On the morning of Day 53, the parent recorded this conversation between the subject and nbaCub, "*Come on Piggy, you're getting too big for me to carry all the time.*"

The planned testing for Phase 3 of the nbaCub in support of the subject's morning routine produced a rating of "very helpful" for 7 of the 8 days it was actually used. The high marks may be explained in this summary of Week 8, "<Subject> was more eager to use and start Piggy because she is not familiar with her morning routine. She did carry Piggy around most of the time after talking to her about her needing to carry Piggy with her." The day it did not receive a "very helpful" rating, it received a "somewhat helpful" rating. The parent commented, "<Subject> was dragging her feet this a.m." For Week 8, the subject started the ambient media display without help on three of the five days.

6.4.3 Post-Testing

The two post-testing questionnaires were fashioned in the same manner as Phase 1 post-testing, except the word "morning" was substituted for "evening or bedtime". Question: "How do you know when it is time to get up in the morning?" Subject's answer: "*Sometimes I get up by myself and sometimes y'all get me up.*" Question: "How long does it take you to get ready to leave the house in the morning?" Subject's answer: "*Piggy gives me 45 minutes.*" Question: "What do you need to do to get ready to leave the house in the morning?" Subject's answer: "*I got to get my lunch put in my backpack get my hair done, brush my teeth and wash my face, get ready for school, then watch T.V. and we leave.*" Question: "What do you need help with when you get ready in the morning?" Subject's answer: "*I need help with doing my hair.*"

The second questionnaire asked the subject about the nbaCub. Question: "What do you like best about Miss Piggy?" Subject's answer: "*I like the kind of Pig she is, what she does and how she looks.*" Question: "Does she help you get ready in the morning? How?" Subject's answer: "*Yes ma'am. She tells me what to do.*" Question: "If you could change anything about your movie (pictures), what would you change?" Subject's answer: "*I would change getting my lunch last and then watching T.V.*" Question: "What are some other things Miss Piggy can help you with, other than getting ready in the morning and getting ready for bed?" Subject's answer: "*Sometimes she can sleep with me but that's it.*"

The Phase 3 post-test evaluation activities were fashioned after Phase 1 evaluation activities. Using the flashcard/question format, the subject answered all the questions correctly in the first activity. For the flashcard with the image of the full routine (all color), the subject answered, "*A lot; much time*", instead of the time quantity of 45 minutes. The second activity involved ordering the flashcards with images of each morning task into the correct order of the routine. The subject correctly ordered the flashcards on the first try, taking five minutes to do so.

6.4.4 Discussion

Like Phase 2, the volunteered extra unscheduled testing of the subject with the nbaCub in the evenings provided interesting information. After being away from the nbaCub for eight days, the subject anticipated the return of an essential part of the DC prototype -- the ambient media display to make the nbaCub complete and usable. It was nice to see the subject proclaim "*I love Piggy!*" The parent noted how the subject "carried Piggy more than she ever has." The subject grew curious enough to learn how to start the display without help, and also learned how to take the display out to be charged. That curiosity satisfied, the subject started to feel the ambient display was not necessarily needed to get ready for bed, because she knew her bedtime routine really well. (Maybe this was in the contrast to her needing the nbaCub for her morning routine because she was still getting used to it.) However, the data shows on the particular evenings she did not use the nbaCub, sometimes the timing of her bedtime routine was off (stretched to over an hour), or she left some routine activities out (bath time).

The fact that the ambient media display was not fabricated correctly in Phase 2b did not spell "doom" for the field study as feared by the investigator. In fact, it produced quite the opposite result. A "very helpful" rating was issued for all but one morning of Phase 3. The highest rating the nbaCub and ambient media display for the bedtime routine ever received was "somewhat helpful". The explanation the parent gave was valid: the subject was more "eager" to use the nbaCub in the morning because the subject felt like she needed it to help her accomplish her routine morning tasks. The regular routine of the family was disrupted when the father was out of town and the mother had to take the subject to school in the mornings. It is possible the "very helpful" ratings were issued by the parent as a nod toward the nbaCub's helpfulness in getting the subject to the point of "free time", so the parent could also get ready to leave. The subject's conversation with the nbaCub was cute: she told her she was getting too heavy to carry all the time. That illustrates her fondness of her DC buddy and possible attitude, you're heavy but you're worth carrying around. Another interesting point was the subject's decision not to return the nbaCub to get the ambient media display for the morning routine replaced once it was discovered to be incorrect. After reuniting with the nbaCub after 8 days of absence, it seems like the subject did not want to give it up again.

The second question in the first Questionnaire of the post-testing produced a surprising answer. For the first time, the subject quantified the time allotted for a routine in an exact number: "*45 minutes*", which was the correct answer. However, when posed the same question in flashcard form (evaluation activity 1), the subject reverted to an answer that was correct, but less specific "*a lot, much time*". Nonetheless, this could possibly be a sign that the subject's understanding of specific time and time passage is improving. Post-testing results show the subject had learned the new morning routine in the two weeks Phase 3 was conducted, although it probably was not familiar at the same comfort level as the bedtime routine (as the subject did not refuse to use the nbaCub and ambient media display for the morning routine during usability testing).

6.5 Phase 4

The test plan for Phase 4 was similar to Phase 3 testing, with the difference of having the subject use the nbaCub and a never-before used ambient media display depicting time passage only to support both the daily morning routine and the daily bedtime routine. This phase was scheduled for two calendar weeks, with weekends off. No pre-testing was necessary in Phase 4. Both weeks (Week 9, Week 10) included a twice-daily observation of the child's morning and bedtime routines with the availability of the nbaCub as a DC toy prototype; and a lightweight ambient media display depicting time-only (see Figure 3) was available to support the child for both routines. Phase 4 concluded with post-testing: two questionnaires and four evaluation activities, designed similarly to Phase 1 and 3 post-testing instruments. A Phase 4 Workbook was provided to the parent data gatherer to serve as a detailed guide and place to record all observations and testing activities.

Prior to the start of Phase 4, the parent understood the planned design of Phase 4 was to conduct testing using the more abstract ambient media display of time passage only. However, the parent expressed concern the subject may not be totally comfortable with her morning routine, and requested permission to use the ambient media display fabricated in Phase 2b for morning usability testing. The following arrangement to try to phase in the time-only routine was made between the investigator and parent. For Phase 4 week 1, the subject would use the morning routine for the first two days only. The parent would try to encourage transition to the time-only routine for the last three mornings of usability testing of the first week. However, if the subject requested the morning routine, the parent would allow the subject to use it, and record the actual ambient media display used. For Phase 4 week 2 mornings and Phase 4 evenings, the parent would try to have the subject use the time-only ambient media display.

6.5.1 Usability Testing

For Week 9 morning usability testing, the subject used the nbaCub every single morning with the ambient media display of the morning routine fabricated in Phase 2b. The parent selected the nbaCub on two of the days, by the subject three days. The subject started the ambient media display with no help on four of the five days. The ratings consisted of three “somewhat helpful”, one “not helpful”, and one “very helpful” votes. The time for the daily morning routines were 45, 40, 60, 40, and 60 minutes; with 20, 16, 33, 10, and 30 minutes of free time as the last task, respectively. The worksheet of the weekly testing summary showed the subject followed the morning routine as depicted on the ambient media display exactly. The parent wrote the following summary of the week, “Piggy was very helpful this week because <Subject> is still trying to learn her morning routine. On average, everything was performed according to routine. The routine did not get started on time this week because Mommy had to take her to school.”

For Week 9 of evening testing, the subject used the nbaCub for all five evenings, with the ambient media display depicting time-only. The subject selected the nbaCub on four of the five days, and started the ambient media display all five days. The rating for the nbaCub was four “not helpful” and one “somewhat helpful”. The time for the daily bedtime routines were 37, 33, 46, 32, and 31 minutes for the week. The subject followed the regular evening routine as depicted on the ambient media display of Phase 1 (although the subject did not use this display during Phase 4 itself). The parent’s summary of the evening testing of the week, “Piggy was somewhat helpful. She understands her bedtime routine, so the movie wasn’t used as often as it should have been.”

For Week 10 of morning testing, the subject used the nbaCub for three of the five mornings of the week. She selected the nbaCub on all three mornings, and also started the ambient media display of the morning routine by herself on the first two days. The first morning she said, "*I need my morning movie to get ready for school.*" On this morning, the nbaCub received a "very helpful" rating. The next two days it received "somewhat helpful" ratings. On the third day the subject started the ambient media display of the time-only routine without help. However, she encountered a technical problem with the nbaCub's PDA display. The subject told the parent, "*Mommy, something is wrong with Piggy!*" The parent explained, "<Subject> started movie, but and error popped up and would not play anymore." The following day the subject asked, "*Mommy, I don't know what to do next! Is my movie fixed yet?*" The parent added, "Movie still broken. <Subject> pretended like she didn't know what to do without her movie. Watched T.V. instead of doing routine. Re-directed her several times." On the last day of the 10-week field study, the subject asked again, "*Is my movie fixed yet?*" The parent logged, "Did not have movie. It was broken." For the three days the nbaCub was used, the morning routine took 45 minutes each day. The end of the week summary logged by the parent stated, "<Subject> was partial to the morning movie. I don't think she really understands the abstract movie that represents time elapsed. She pretty much started her morning routines on time."

For Week 10 of evening testing, the subject was only able to use the nbaCub for three evenings, because of the technical difficulties with the nbaCub DC prototype. The parent selected the nbaCub on the first evening; the subject selected the nbaCub the next two evenings. The subject started the ambient media display of time-only without help all three evenings. It received two "not helpful" ratings and a "somewhat helpful" rating. On the second evening of the week, the parent noted, "<Subject> not really interested in Piggy's movie." On the third evening, the parent observed, "<Subject> carried Piggy, but she was not exactly paying attention to the movie. I don't think she understands the abstract movie." On the fourth evening, the nbaCub was unavailable because of an error on the display computer. The subject asked, "*Is my movie fixed yet?*" The time elapsed for the bedtime routines for Week 10 was 59, 27, and 34 minutes. The final end of the week summary stated, "<Subject> usually started her routine early for bedtime. Piggy was not very helpful this week. <Subject> could only tell when it was close to being bedtime, or when her time was all out.

6.5.2 Post-Testing

The two post-test questionnaires used in Phase 4 were based on Phase 1 and Phase 3 post-testing. Basically, the same questions were asked. Question: "How do you know when it is time to get up in the morning?" Subject's answer: "*My mommy or daddy wake me up.*" Question: "How long does it take you to get ready to leave the house in the morning?" Subject's answer: "*About 10 minutes.*" Question: "What do you need to do to get ready to leave the house in the morning? Subject's answer: "*I need to get my backpack ready, get my mommy to do my hair, brush my teeth/wash my face, then get my school clothes, and then I have free time.*" Question: "What do you need help with when you get ready in the morning?" Subject's answer: "*My hair.*" Question: "How do you know when it is time to go to bed at night?" Subject's answer, "*Piggy tells me.*" Question: "How long does it take you to get ready for bed at night?" Subject's answer, "*I don't know.*" Question: "What do you need to do to get ready for bed at night?" Subject's answer: "*I need to brush my teeth, and get my bath, get my school clothes, my night clothes, read a book, and pray.*" Question: "What do you need help with when you get ready for bed?" Subject's answer: "*I need help with reading my book and getting my bath water ran.*"

The second questionnaire asks the subject about the nbaCub. Question: "What do you like best about Miss Piggy?" Subject's answer: "*Her fur.*" Question: "Does she help you get ready in the morning? How?" Subject's answer: "*Yes. She tells me what to do.*" Question: "Does she help you get ready for bed at night? How?" Subject's answer: "*Yes. By telling me when to brush my teeth, when to take a bath, to get my* *school clothes, to read my book, and to go to bed.*" Question: "If you could change anything about the movies (pictures), what would you change?" Subject's answer: "*I would change my lunch to after I get my bed clothes.*" Question: "What are some other things Miss Piggy can help you with, other than getting ready in the morning and getting ready for bed?" Subject's answer: "*She can sleep with me at nighttime.*"

Two of the post-test evaluation activities for Phase 4 included giving the subject flashcards with images of actual routine activities, and having the subject put them in the correct order. The subject correctly accomplished the morning routine evaluation activity on the first try, in one minute. The subject also correctly ordered the bedtime routine flashcards on the first try, in two minutes.

The last two evaluation activities were similar to Phase 1 and Phase 3 evaluation activities, except the subject was shown images taken from the ambient media display of time-only. For each image, the subject was asked a question relating to either the time left in routine or what activity would be next. For the image that was totally black, the subject correctly answered there was no more time to get ready in the morning. For the image that showed the entire dcWorld (full color image of a circle), the subject answered she had "*Lots*" of time, instead of answering 45 minutes or running down the list of activities. For the image that showed 1/3 of the time missing, the subject correctly answered "*brush teeth and wash face*", and for the image that showed 1/3 of the time remaining, the subject correctly answered "*free time*".

In the next evaluation activity based on the bedtime routine, for the image that depicted 10 minutes remaining, the subject answered "*Just a little bit*". For the image that showed the entire dcWorld, the subject answered she had "*A lot*" of time, instead of answering 45 minutes or running down the list of activities. For the image that showed 25 minutes had elapsed with 20 remaining, the subject answered, "*Read my book and go to bed*" instead of the correct answer "pick out lunch". On the final image that showed

30 minutes had elapsed with 15 remaining, the subject again answered, "*Read my book*". This was the correct answer. Of the eight questions, the subject missed only one.

6.5.3 Discussion

Phase 4 testing showed the subject continued to rely on the nbaCub and the ambient display of the morning routine fabricated in Phase 2b up until the DC prototype was no longer available due to malfunction of the PDA. The parent made a comment the subject was still in the process of learning the morning routine during the first week of Phase 4 testing. Post-testing results point to the fact the subject listed all morning routine activities in the correct order, and probably did not require it for the last week of testing. However, it was her desire to continue to use it, which the subject demonstrated on the morning of Day 67 when she was uncooperative with performing her morning routine without the help of the nbaCub DC buddy. The problem with the PDA was not reported to the investigator until after the end of the study. It was unfortunate the 10-week study had to end on a note where the subject's last interaction with the nbaCub DC prototype was to see "*something is wrong with Piggy*". Perhaps it made the transition to owning the replacement Miss Piggy (duplicate stuffed animal purchased in Phase 0a) easier, to know that the nbaCub was not working properly. (In informal conversation after the study ended, the parent told the investigator the subject was told the new Miss Piggy was the nbaCub's "sister". The subject did ask for the nbaCub back several times before resigning herself to the new version of her stuffed pig.)

Phase 4 evening testing observations by the parent discussed the fact the subject did not prefer or seem to understand the ambient media display of time passage only. The subject would start the display but ignore it while still carrying the nbaCub around with her to perform her routine. Post-testing with the images of the ambient media display of time-only showed only one incorrect answer out of 8, so it is possible that the subject understood it more than she herself knew or wanted to. By the end of the 10-week field study, the subject definitely had her bedtime routine down pat. In Phase 4 post-testing, the subject made a reference to the nbaCub's ability to "*sleep with me at nighttime*". The fact that the nbaCub bedtime buddy still held that honor at the end of the ten-week field study was very nice to know.

6.6 Closing Summary

Our testing of the nbaCub DC toy prototype with a child (human) subject and an outside data gatherer (the parent) in their home environment for an extended period of ten consecutive weeks turned out to quite an undertaking, but one well worth the effort. The research study was designed to be an informal, proof of concept of what Display Computers for children can look like and be used for in the near future. Personalizing the design of the nbaCub form factor and ambient media displays to the preferences and personal belongings of the young user in Phase 0 definitely contributed to the positive outcome of the study. In Phase 1, the subject had no problem adopting the nbaCub and relied on the visual images provided on the ambient media display to keep within the planned time frame of the bedtime routine. The subject even suggested the nbaCub might be of further help with the required task of hand washing throughout the day. Phase 2 brought a surprising but welcome request from the parent to extend the usability testing of the nbaCub in the evenings. Although the nbaCub was only used a little over half of the time, the subject learned the nbaCub form factor and the ambient media display were two separate entities that could be separated. Through the extended testing period, the subject came to feel she understood her bedtime routine enough and showed signs of ignoring the ambient media display of the evening routine while still carrying the nbaCub as a bedtime buddy. However, this behavior tended to result in bedtime routines that extended beyond the allotted time. The test by design activity in Phase 2a was not as rigorously carried out per the test plan. A family emergency forced a quick transition of notes and materials between the investigator and parent, ultimately leading to the incorrect fabrication of the new ambient morning routine in Phase 2b. The consequences of the seemingly problematic error unexpectedly resulted in increased usage and higher rating of the nbaCub in Phase 3 testing of the morning routine. At one point the subject proclaimed, "*I love Piggy!*" In post-testing, the subject for the first (and only time in the study) discussed time as an exact quantity stating, "*Piggy gives me 45 minutes"* to get ready in the morning. To close the 10-week field study, in Phase 4 the subject showed preferences of needing and using the morning routine; knowing the bedtime routine well enough to ignore the new ambient media display of time passage only, while still preferring to carry around the nbaCub as a bedtime buddy. Three days before the study was scheduled to end, the nbaCub DC prototype malfunctioned and was not available to support either of the subject's routines the final three days. The subject reacted by repeatedly asking if it had been fixed, and then pretending that she no longer knew how to perform routine morning tasks without the help of her nbaCub DC toy prototype. The final post-testing showed the subject knew both morning and bedtime routines very well, and correctly answered seven of eight questions based on abstract images of time passage taken from the ambient media display of time-only. A safe conclusion would be that the subject was in the process of learning the more abstract concept of time passage, but was not totally comfortable with the idea at the end of the informal research study. At the close of the study, the parent returned the nbaCub and other research materials to the investigator, who provided a replica of the stuffed pig (complete with clothing and accessories) to be given to the subject to keep.

7. CONCLUSION

From our informal study, we have observed a kindergarten-aged child can learn, practice and begin to understand abstract concepts such as time and routines with the help of a personal DC toy. Visual cues presented step-by-step in real-time, can help with the visualization and understanding of time passage and the "to-do list" required to perform routine activities. The emphasis of the DC application is to provide lightweight information in the form of ambient media that promotes the positive, seamless, and calm use of technology by a young child.

The nbaCub prototype illustrates a sample application of how Display Computers can be useful in the everyday environment of the home of the future. Embedding a computer into a toy, such that the display is the only visible portion, can present many opportunities for seamless and non-traditional uses of computing technology for our youngest user community. With nbaCub, we are providing lightweight, ambient information to kindergarten-aged children through a familiar "buddy" willing to accompany them as they go about performing the necessary daily routine of preparing for bed.

With our DC toy prototype, nbaCub, we have demonstrated that: DCs are appropriate for everyday usage; provide novel form factors; provide single function, simple to use application delivery systems; and, provide many opportunities for the delivery of novel applications to children. The nbaCub is a Display Computer prototype. As a stuffed animal, it has already been adopted and given the special status of a nightly bedtime buddy. As a DC toy, the motivation already exists for carrying it around. The calm technology provided by the DC is in effect, a nice bonus. As an application delivery system, the single function is the seamless delivery of lightweight information in the form of ambient media to the display on the cub's shirt. Any minimal interaction required is natural and simple. As a novel application for a child, the delivery of the abstract concepts of "time" and "routine" is unique. Through consistent visual cues that support the learning and practice of the everyday activities of a child getting ready for bed, the understanding of the concept of time and routines should start to take shape or be reinforced.

As stated by Mark Weiser, "Applications are of course the whole point of ubiquitous computing." [217] Display Computers offer novel form factors with which to deliver computing applications to children. The ability to pair different scales of visual displays with unique and flexible substrates (plastic, cloth, glass, etc.) on everyday items they are already familiar with, presents an opportunity too good to resist. The Display Computing paradigm thus represents a brand new horizon for children and their use of technology. We believe this new genre of applications will enable children of all ages to use DC toys as tools to support everyday activities in a seamless manner, every day of their lives.

We have demonstrated a kindergarten-aged child can learn, practice and begin to understand abstract concepts such as time and routines with the help of a personal DC toy. Visual cues presented step-by-step in real-time, can help with the visualization and understanding of time passage or the "to-do list" required to perform routine activities. The emphasis of the DC application is to provide lightweight information in the form of ambient media that promotes the positive, seamless, and calm use of technology by a young child.

The innovative and emerging technology that will make Display Computers affordable and available to everyone, will effect change in the way information is presented and used by individuals in the living of their daily lives. Especially exciting is the wide range of opportunities presented by DCs to dramatically broaden the horizons of children in their use of advancing technology of the future. The visionary computing ideas of the past and present, coupled with current and future technological advancements, provide ample foundations to enable children of this and future generations to soon find themselves living in a environment that is enriched and saturated with DCs for their every need and want.

Now is the best time and opportunity for application developers to start thinking “out of the box” in Visionary Computing terms. While the development of the technology to make Display Computers a reality for the future is ongoing, we should also be researching and designing the new genres of applications that will enable everyday people, especially children, to make maximum use of the DCs that will saturate their everyday environment in the future. Designers must start determining how to take advantage of the broad flexibility of form factors and display characteristics available with DCs. They have the unique opportunity to customize and personalize DCs as information delivery systems dependent on the age of the intended user and the functionality of the specific application.

Display Computers will masquerade as everyday objects, but have the unique ability to provide novel and useful support in the daily lives of their everyday users, including the youngest school-aged child. The key to widespread adoption of DCs for children in the future will be their low-cost availability and widespread development of a new genre of ubiquitous Display Computing applications.

As a final analogy, we propose that what the personal computer and desktop computing applications did to open up business computing for home and office use, so will Display Computing and its new genre of applications open up everyday computing for everyday people, everyday of their lives. However, we place great emphasis on the need to concentrate design and development efforts of Display Computing applications for children first and foremost, because they represent the future of our world, and they have been largely left out of the computing revolution … until now.

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APPENDIX A
RESEARCH PROCEDURES

Appendix A contains detailed Research Procedures for the Display Computer Prototype field study of Section 5. The research procedures were submitted and approved as part of the IRB application, required documentation of the proposed human subjects research protocol by the Texas A&M University Institutional Review Board.

IRB Application: Part II Research Protocol

Part A, Item 3. Research Procedures

Submitted to the Institutional Review Board of

Texas A&M University

Submitted by: Lisa M. Smith

November 2004

Child's Play:
A Display Computer Prototype Study

Research Procedures
Table of Contents

"For almost three decades, personal computers (PCs) have been part of the computing infrastructure, bringing the power of word processing, spreadsheet and database applications into the home. Portable computers and laptops have allowed professionals to take their PCs 'on the road.' More recently, Personal Digital Assistants (PDAs) have offered calendar and time management applications for the busy professional. The emerging new tablet computers augment laptops with slimmer and lighter form factors and note-taking/annotation applications, and promise to usher in a new computing revolution.

Impressive as the current penetration of computing is into the fabric of everyday life, it will pale in comparison to the coming revolution brought on by Display Computers (DCs). DCs are so named because, to the average person, they are simply displays. The physical size of the display vis-à-vis the physical size of the human will allow for the computer, wireless networking, and storage to be manufactured 'in the margins'. New low-power, thin, light, and bright displays will become the standard viewing surface throughout the workplace and the home."

-- John Leggett [1]

1 Display Computers

The term Display Computer (DC) at first glance seems easy enough to define: Display Computer = Display + Computer. The "Display" part is the standard viewing surface found on everyday objects that conveys information or art and is found in everyday environments, indoors or out. The "Computer" is found on the same everyday object, but by its ubiquitous nature will be relatively unnoticeable by the DC user, as it is manufactured "in the margins" [1].

Some fundamental characteristics of Display Computers are also easy to list. A Display Computer may be mobile [2], moving with us as part of the everyday object we are using. Display Computers will be ubiquitous: "effectively invisible" [3], available at a glance, and seamlessly integrated into the environment [4, 5]. A DC should be an example of Weiser's calm technology [6, 7]: encalming to the user, providing peripheral awareness without information overload. A DC should provide unremarkable computing in support of our daily routines in life [8].

But Display Computing requires a totally different way of thinking and it is difficult to disregard our learning and experience with the traditional desktop metaphor. This is not a new problem in the history of Visionary Computing. Researchers who chose to follow the visionary ideas of the past have always had to learn to think in radically different ways.

Current research and development efforts will lead to advances in fabrication methods and new technologies that will make DCs possible. When these technologies become affordable enough to mass market to the general public, our world will change right before our eyes. Novel form factors to deliver unique applications will be commonly available with the advent of Display Computers. These new paradigms of use are based on the needs of Display Computer users: the children, parents, and extended members of families.

1.1 Purpose

The nbaCub prototype illustrates a sample application of how Display Computers can be useful in the everyday environment of the home of the future. Embedding a computer into a toy, such that the display is the only visible portion, can present many opportunities for seamless and non-traditional uses of computing technology for our youngest user community. The purpose of this study is to observe and evaluate the use of the DC prototype as a novel and practical toy-and-tool-in-one. With nbaCub, we are providing lightweight, ambient information to kindergarten-aged children through a familiar "buddy" willing to accompany them as they go about performing the necessary daily routines of preparing for bed (evening routine), and preparing to go to school (morning routine).

Figure 1. Original leopard cub.

1.2 Hypothesis

It is our prediction that a young child can learn, practice and begin to understand abstract concepts such as time and routines with the help of a personal DC toy. Visual cues presented step-by-step in real-time, can help with the visualization and understanding of time passage and the "to-do list" required to perform routine activities. A deeper understanding of the child's progress towards learning abstract concepts of time passage and routines will be gained through a "Test by Design" activity where the child is the primary designer or director of an everyday routine. By the end of the study, we believe the child will be able to generalize these concepts to other everyday routine activities, thereby only requiring the nbaCub to help out with time visualization (no task list).

1.3 Field Study Overview

A field study has been chosen to test the usability of the nbaCub in the natural home setting. The child will be given access to the nbaCub DC toy prototype in his home environment. A lightweight information display will appear on the nbaCub's shirt each evening before bedtime. The child will then participate in a Test by Design activity to design and direct a lightweight display of a morning routine. This visualization will combine both concepts of "time passage" and "routines" (to-do list task images) and will be used for the lightweight display in the next phase. Final testing will use an ambient media display that only visualizes time passage. One goal of this study is to "observe process or technology in situ, disturbing the system we observe as little as possible" [9]. Thus testing will be informal in procedure and observation and will be conducted by the child's parent in their home over a period of 10 consecutive weeks.

2 Research Design

A field study has been chosen to test the usability of the nbaCub in the natural home setting. The goal of this research strategy is to "observe process or technology in situ, disturbing the system we observe as little as possible" [9].

2.1 Required Materials

2.1.1 nbaCub

The **nbaCub** (**n**ightly **b**edtime **a**mbient **C**ues **u**tility **b**uddy) is a custom-made stuffed leopard cub [10] (see Figure1). In this Display Computer toy prototype, we will replace the "NBA 1" portion of the cub's shirt with a Palm Tungsten T3 handheld personal digital assistant (PDA) running Palm OS v. 5.2.1. The PDA, with built-in Bluetooth for wireless communication, has a 320x480 transflective TFT display supporting over 65,000 colors that can be rotated from portrait to landscape mode.

The personalized nature of the nbaCub to the target user (child subject) is of utmost importance to this research study. If necessary, a form factor that differs from the leopard cub will be used as the Display Computer toy prototype. In addition, the ambient media display should be personalized with both visual images and a bedtime routine that are familiar and meaningful to the young user.

2.1.2 Ambient Media

The DC prototype will show a lightweight visualization (no audio) of "time passing" in the forty-five minutes before the child's bedtime. Several different methods exist for displaying time passage cues through ambient media, from "least ambient" to "most ambient". In this study, the two lightweight displays (a) and (b) will be used. While (a) is a hybrid display of both task and time passage, (b) shows time passage only. Note that option (b) is more general than (a). See Table 1; Figures 2 and 3. Option (c) will be a visualization directed and designed by the subject during the study.

	lightweight display	**symbols/colors**	**description**
a	**to-do list on pie chart** ***ambient nighttime routine with time passage***	**circle, pie slices with task images black**	**start with round circle with task images on pie slices in order of routine; overlay darker pie slice on top of image when the timeslice is up**
b	**dcWorld (pie chart)** ***ambient time passage***	**circle, pie slices, round world image black**	**start with round image of world; every 5 min. overlay black ("night") pie slice; 9 slices total for 45 minutes, at 5 min. each**
c	***ambient morning routine with time passage***		*To be designed by subject during Phase 2 of study.*

Table 1. Lightweight Ambient Display Media.

2.1.3 Interaction

Each of the four hardware buttons on the PDA will be set to automatically open the media player application. The PDA display is sensitive to touch via stylus or small fingers for input capabilities. *Chapters* (such as those found on DVD movies) defined at 45, 30, and 15 minutes will add a level of interaction and choice for the start length of the lightweight display. (See Figure 3 on page 22 for an example.) The final chapter lasts for 5 minutes, making each full-length display a total of 50 minutes long.

The PDA will be secured in the toy to be mobile and "safe" during a child's daily use, including expected levels of "wear and tear". The PDA must be easily retrievable from the DC form factor by an adult, however. Events such as recharging the battery, syncing the PDA with the "home" computer for transfer of ambient display media, and removal of the peripheral memory card will be required on a regular basis.

2.1.4 Fabrication

The ambient media designed by the subject during the study will be made into a movie by the investigator using iLife '04 software for Mac OS X. The subject will design or specify which personal paper media (including scrapbook art and original artwork) and/or everyday personal items or toys are representative of morning routine tasks. Photographs taken with a digital camera will be used as still images in a movie viewable on the Kinoma Player application using the PDA. The subject will direct the order and timing of the task images to complete the movie specification.

2.2 Required Personnel and Roles

One child subject will be required to carry out the study. Because the study will take place in the subject's home environment, the mother of the child will take part in the study as a data gatherer to observe and evaluate the child, and act as a facilitator during design sessions. Regular contact between the parent data gatherer and investigator during the course of the study will be required.

2.2.1 Subject

Druin discusses four roles children can have in the design and development of "new technology": user, tester, informant, and design partner [11]. The child participating in the ethnographic study of this prototype will play two of these roles: user and tester. In this study, our child does not fit the roles of informant and design partner as described by Druin, because he does not actively take part in the research or the design of the nbaCub prototype from the beginning. However, we have identified a new role the child will play in the "Test by Design" activity, that of primary designer or director.

<u>Child as User</u>. In observing the role of the child as a *user* before and after the novel form factor and ambient displays ("new technology") are introduced, we hope to understand what effect they have had on his understanding of time and routines ("learning experience").

Child as Tester. Using an "initial" prototype that has already been designed and created by adults, places the child in the role of a *tester*. Here again, simple observation, along with simple questions for "direct feedback", should help us to understand what impact the new technology has had on the child tester.

Child as Primary Designer/Director. After the initial usability study is completed, we will have the child "direct" his own personal ambient media display for use on the nbaCub bedtime buddy. An example of a routine that would be very similar in concept to the bedtime routine but require a different set of visual cues and time line, would be a morning routine to help him get ready for school. As the *primary designer* or *director* (as opposed to equal design partner in participatory design [11, 12]), he will have to express his concept of time in order to design prototypes of his ideas. The ambient media content could be personalized with his choice of original artwork or favorite belongings found around his home.

2.2.2 Data Gatherer

The "data gatherer" role is flexible and can be filled by one or many adults, namely: a parent, ethnographer, or investigator. In this study, the mother of the child will play this role. Having an outsider (ethnographer or investigator) in the household for the extended time period required by the study would most likely be too disruptive. It is important that consistent documentation of all observations and evaluations are kept. A workbook with all necessary forms will be provided.

Parent as Designer. Prior to the 10-week field study with the child subject, the parent and the investigator will work together to design a custom nbaCub Display Computer prototype specifically personalized to the child subject. Thus, in Phase 0, the parent is the primary designer and director, while the investigator is the facilitator and fabricator. Note this exercise will be repeated during the Phase 2 Test by Design sessions, where the parent will become facilitator, with the child being the primary designer and director.

Data Gatherer as Observer. During the entire study, a daily log of the time the child started getting ready for bed, the actual bedtime, any use of chapters, and additional free-form notes of any unsolicited comments the child makes pertaining to their access or use of the nbaCub and the lightweight information displays should be recorded by the parent data gatherer.

Data Gatherer as Evaluator. Each phase is divided into pre-testing, testing, and post-testing. The pre- and post-tests should provide a measure of the before and after knowledge and understanding of the abstract concepts of "time passage" and "routine" by the child. For example, during pre-testing the parent data gatherer might ask a simple list of open-ended questions about getting ready for bed.

Data Gatherer as Facilitator. The parent data gatherer taking part in the "Test by Design" activity and design sessions will fill the role of design "facilitator". Note that while it would be desirable to complete the design in one session, it may be necessary to have multiple sessions to finish the specifications for a prototype. Because the child is the primary designer, he should be the person to decide when the design is "finished". In addition, it may be the case that during usability testing of the nbaCub with the new routine, the child as the primary designer/director/user/tester may come to realize the design is not complete and wish to modify the design. In such a scenario, the field study should be flexible enough to allow for iterative design sessions that can produce multiple, rapid prototypes of ambient media displays undergoing the complete cycle of design, fabrication, and usability testing.

2.2.3 Investigator

The investigator will play the role of "producer" of the actual ambient media, and "fabricator" of the resulting prototype into a lightweight display viewable on the nbaCub for actual use in support of the new routine.

2.3 Methodology

Because the personalized nature of the nbaCub to the target user (child subject) is of utmost importance to this research study, a form factor that differs from the leopard cub will be used as the Display Computer toy prototype. Thus, in Phase 0 (see Table 2), prior to the 10-week field study with the child subject, the parent and the investigator will work together to design a custom nbaCub Display Computer prototype specifically personalized to the child subject.

Testing	Role of Child	Pre-Test	Test Activity	Post-Test
Phase 0a	target user	N/A	investigator and parent work together to design personalized nbaCub and ambient media display (similar to prototype (a)) for the child subject's bedtime routine	N/A
Phase 0b	N/A	N/A	investigator fabricates personalized ambient media display for R1	N/A

Table 2. Overview of Phase 0, to be completed prior to 10-week DC prototype field study.

The overall design of the ten-week field study will involve four phases (see Table 3). The testing will be informal in procedure and observation. The child will be given access to the nbaCub DC toy prototype in his home environment. A lightweight information display will appear on the nbaCub's shirt each evening before bedtime. Two lightweight display types (see Table 1) will be used during testing. The visualization (a) combines both concepts of "time passage" and "routines" (to-do list task images) and will be used for the lightweight display in Phase 1, and as the model for Phases 2 and 3. Phase 4 will use an ambient media display that only visualizes time passage (b).

Testing	Role of Child	Pre-Test	Test Activity	Post-Test
Phase 1	user tester	concepts of time passage and bedtime routine (R1)	child uses nbaCub to support bedtime routine (R1); ambient media display (a)	understanding, learning of time passage and bedtime routine (R1); evaluation activities
Phase 2a	designer director	concepts of time passage and morning routine (R2)	*design session(s) of new ambient media display(c) for new morning routine (R2): child as designer/director; adult as facilitator*	N/A
Phase 2b	N/A	N/A	*adult as producer/fabricator of ambient media application designed by child (R2)*	N/A
Phase 3	designer director user tester	N/A	*child uses nbaCub to support new morning routine (R2) he designed/directed (c) [based on ambient media displa (a)]*	understanding, learning of time passage and morning routine (R2); evaluation activities
			activities in Phases 2a, 2b, 3 (prior to Post-Test) may be repeated if child desires	
Phase 4	user tester	N/A	child uses nbaCub to support R1, R2; ambient media display of time passage only (b); no task image to-do list cues;	understanding, learning of time passage; bedtime (R1) and morning routine (R2); evaluation activities

Table 3. Methodology of proposed 10-week DC prototype field study.

2.3.1 Evaluation

Each phase is divided into pre-testing, test activity, and post-testing where applicable. The pre- and post-tests should provide a measure of the before and after knowledge and understanding of the abstract concepts of "time passage" and "routine" by the child. For example, pre-testing in Phase 1 might include a simple list of open-ended questions about getting ready for bed. Possible questions include:

(1) How do you know when it is time to get ready for bed?
(2) How long does it take for you to get ready for bed?
(3) What do you need to do to get ready for bed?
(4) How do you know when it is time to get into bed?

The same set of questions will be asked in the post-testing period. It is expected that the answers to the post-testing questions will be in more detail than before testing. An additional list of questions will be administered in each post-test period. These questions will be geared to finding out what the subject thought about the nbaCub, and if and how nbaCub helped them in getting ready for bed.

During the entire informal evaluation period, a daily log of the time the child started getting ready for bed, the actual bedtime, any use of chapters, and additional free-form notes of any unsolicited comments the child makes pertaining to their access or use of the nbaCub and the lightweight information displays will be recorded in the form of handwritten documentation.

Of primary interest, is whether the child's understanding of the two abstract concepts (passage of time, routine) improved after using the nbaCub DC prototype and ambient media application. Thus, in addition to the questions and logs, an evaluation activity to take place in the post-test period will consist of asking the child simple questions about time passage based on scenes taken from the lightweight displays, or asking him to demonstrate simple tasks such as ordering of the to-do list (bedtime routine tasks) using flashcards illustrated with ambient media elements.

2.3.2 Test by Design

To provide a deeper understanding of the child's progress towards learning of the abstract concepts of time passage and routines in Phase 1, Phase 2a will entail a "Test by Design" activity where the child is the primary designer or director of a similar, but different everyday routine. Phase 2b concludes with the actual fabrication of a prototype movie that can be viewed on the nbaCub DC prototype. Phase 3 is basically a repeat of Phase 1, the only difference being the everyday routine that is being used and tested (morning routine instead of bedtime routine), and the fact that a pre-test is not necessary, having been performed already in Phase 2a. It is expected that the child will show better understanding of the morning routine and time passage in the post-test results of Phase 3, by simple virtue that he was the primary designer of the ambient media display. Note the activities of Phase 2a, 2b, and 3 may be repeated several times if the "child as primary designer" wishes (he believes and the adult agrees it may not be "finished"). Thus, the child may participate in one or more design cycles.

2.3.3 Final Testing

The final phase, Phase 4, will repeat the Phase 3 testing with the nbaCub, with two differences. The nbaCub will be used every morning and evening, and the ambient display will no longer show visualizations of the to-do list, but offer only the lightweight passage of time. We believe that after Phases 1, 2, and 3, the child will have a firm enough grasp on the concept of routine and the specific bedtime and morning routines expected of him, that he will be ready to perform his everyday routine activities with the nbaCub buddy showing only ambient displays of time passage (b).

3 Research Procedures

3.1 Phase 0a

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 0a	target user	N/A	investigator and parent work together to design personalized nbaCub and ambient media display (similar to prototype (a)) for the child subject's bedtime routine	N/A

Table 1. Overview of Phase 0a of research study.

3.1.1 Required Materials

Personal artwork or items belonging to child
Digital camera
Tripod
DC form factor: a bedtime buddy and clothing chosen by child (nbaCub)

3.1.2 Required Personnel and Roles

child as target user (chooses a bedtime buddy and clothing)
parent as co-designer
investigator as co-designer, fabricator

3.1.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
N/A	12-13-04 (M)	2	U0	Design a personalized bedtime routine (R1) for target user (to be used in Phase 1 testing)	A0a

Table 2. Phase 0a Test plan, sample schedule.

3.1.4 Procedures

U0 Design of personalized ambient media R1 for child subject as target user.

- ❑ 1. Define evening activities in subject's regular bedtime routine.

The investigator should explain the purpose and guide the activities of the design sessions, but let the parent be primary designer and director of the actual bedtime routine R1, to be used in Phase 1.

- ❑ 2. Take a digital photograph of each defined bedtime activity.

Each activity should be represented in a concrete and personal way, so as to be immediately recognizable to the target user. Personal artwork and items, or personal favorites can and should be used as applicable.

- ❑ 3. Define a 45-minute timeline for the evening's activities to form a routine.

Each evening activity should be placed in a logical order and assigned an appropriate five, ten, or 15-minute block of time. Because the subject may not always have the maximum time to get ready, essential activities should be placed near the end. (See the prototype ambient media (a) for an example.)

- ❑ 4. Define chapter names for each morning activity.

Defining logical chapters will enable the subject to enter the bedtime routine at a different point if the desired 45 minute time period is not available due to special circumstances of the day. If possible, the 45, 30 and 15-minute chapters should be named as such, and other entry points can be named as applicable.

- ❑ 5. Documentation of Phase 0a.

No electronic recording of the design sessions will be made. Fill out form A0 to serve as design documentation for Phase 0b.

- ❑ 6. Take the child subject to pick out a "bedtime buddy" and outfit, to be used as the form factor for the DC prototype used during the remaining phases of testing.

3.2 Phase 0b

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 0b	N/A	N/A	investigator fabricates personalized ambient media display for R1	N/A

Table 3. Overview of Phase 0b of research study.

3.2.1 Required Materials

Digital camera photos
Mac OS X
- iLife '04 (iPhoto, iMovie, iDVD)
- QuickTime
- Kinoma Producer

Bedtime buddy chosen by child (nbaCub)
Tungsten T3 PDA and external media card

3.2.2 Required Personnel and Roles

investigator as fabricator

3.2.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
N/A	12-15-04 (W)	3-13	U0	Fabricate personalized bedtime routine (R1) as a QuickTime, then Kinoma movie; Fabricate evaluation activities E1, E2, to test understanding of time passage and bedtime routine (R1)	A0b E1 E2

Table 4. Phase 0b Test plan, sample schedule.

3.2.4 Procedures

U0b Fabrication of new ambient media, testing materials, and DC toy.

- ❑ 1. Obtain design of R1 from Phase 0a.
- ❑ 2. Fabricate an ambient media display representing the new routine, R1.
- ❑ 3. Create evaluation activities for Phase 1 post-testing.
- ❑ 4. Bedtime buddy form factor must be modified such that PDA is embedded to create a display computer (DC) prototype to be used in this research study.

3.3 Phase 1

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 1	user tester	concepts of time passage and bedtime routine (R1)	child uses bedtime buddy display computer (nbaCub DC) to support bedtime routine (R1); ambient media display (a) usability testing U1	understanding, learning of time passage and bedtime routine (R1); evaluation E1, E2

Table 5. Overview of Phase 1 Testing.

3.3.1 Required Materials

bedtime buddy DC (nbaCub)
ambient media on external card
Kinoma movie (routine R1) (similar to figure 2, lightweight display (a))
PDA battery charger

3.3.2 Required Personnel and Roles

child subject as user, tester
parent/data gatherer as observer, evaluator

3.3.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
[0] [1]	1-3-05 (M)	all (20)	L1	Log bedtime routine activities and comments	L1-[1..20]
[0] [6]	1-8 (Sa)	1	Q1	Test concepts of time passage and bedtime routine (R1)	A1a
[0] [7]	1-9 (Su)	1		off (rest)	
[1] [8]	1-10 (M)	5	U1	child uses nbaCub to support bedtime routine (R1) with display (a)	A1b
[1] [13]	1-15 (Sa)	2		off (rest)	
[2] [15]	1-17 (M)	5	U1	child uses nbaCub to support bedtime routine (R1) with display (a)	A1c
[2] [20]	1-22 (Sa)	1	Q1 Q2	Test concepts of time passage and bedtime routine (R1)	A1d A1e
[2] [20]	1-22 (Sa)	1	E1 E2	Evaluation of understanding of time passage and bedtime routine	A1f A1g

Table 6. Phase 1 Test plan, sample schedule.

3.3.4 Procedures

U1 Evening Routine.

- ❑ 1. Specify target bedtime and target start time.

The target bedtime and target start time for the subject should be the same every evening. Since each day is always different, the actual start time to get ready for bed may differ slightly every evening. The best scenario is to allow the subject the maximum time (45 minutes) to get ready for bed. The minimum time should be no less than 15 minutes. The third option is 30 minutes. The less time, the fewer routine activities the subject is expected to perform.

- ❑ 2. Select DC prototype nbaCub.

Hopefully the subject will select the nbaCub every evening on his own initiative after one reminder that it is time to get ready for bed. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around before bedtime.

- ❑ 3. At target start time, start lightweight display (a) on DC prototype nbaCub.

If the subject is able and interested, he should be able to start the lightweight display at the appropriate target start time (with help if necessary). If less than the maximum time is available, the parent may wish to help the subject use the chapter feature to start the display at another increment.

- ❑ 4. Calculate target end time.

Target end time is actual start time plus the time selected for actual routine (45, 30, or 15 minutes).

- ❑ 5. Subject carries the nbaCub while embarking on a bedtime routine.

Hopefully the subject will carry around the nbaCub consistently while performing routine bedtime activities. If necessary, the parent may give the nbaCub to the subject and with a reminder to carry it around until bedtime. The observer should unobtrusively keep tabs on the subject and his progress throughout the routine.

- ❑ 6. At target end time, subject and nbaCub should be in bed.

Each lightweight display is actually 50 minutes long instead of 45 minutes. That gives the subject an extra minute or two if necessary, to get into bed. The parent(s) should have a couple of minutes to tuck the subject in and say final “good nights” to the subject and nbaCub.

- ❑ 7. Documentation of evening’s activities.

Observer should record the evening’s observations on the appropriate forms as quickly and accurately as possible.

- ❑ 8. Charge up the battery of the nbaCub PDA before next use.

3.4 Phase 2a

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 2a	designer director	concepts of time passage and morning routine (R2)	*design session(s) of new ambient media display(c) for new morning routine (R2): child as designer/director; adult as facilitator*	N/A

Table 7. Overview of Phase 2a Testing.

3.4.1 Required Materials

Personal artwork or items belonging to child
Digital camera
Tripod

3.4.2 Required Personnel and Roles

child subject as primary designer or director of morning routine (R2)
parent/data gatherer as facilitator

3.4.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
[3] [21]	1-23-05 (Su)	All (22)	L2	Log morning routine activities and comments	L2- [21.. 42]
[3] [21]	1-23 (Su)	1	Q3	Test concepts of time passage and morning routine (R2)	A2a
[3] [22]	1-24 (M)	7	U2 D1	design session(s) of new ambient media display (c)	A2b D1- [1..x]
[4] [29]	1-31 (M)	7	[U2] [D2]	off, if task completed, or continue design sessions	[A2b [1..x]] D2- [1..x]

Table 8. Phase 2a Test plan, sample schedule.

3.4.4 Procedures

U2 Test by Design Sessions.

❑ 1. Define morning activities in subject's regular morning routine.
The adult (parent/data gatherer) should explain the purpose and guide the activities of the design sessions, but let the subject be primary designer and director of the new morning routine R2. Define the first activity and the final activity. For example, the first might be to "wake up" and the last to "get into the car to go to ____________".

❑ 2. Take a digital photograph of each defined morning activity.
Each activity should be representable in a concrete and personal way to the subject. For example, breakfast may be represented by the subject's favorite cereal or pop-tart. Personal artwork may be used, or the subject may choose to draw a new picture.

❑ 3. Define a 45-minute timeline for the morning's activities to form a routine.
Each morning activity should be placed in a logical order and assigned an appropriate five, ten, or 15-minute block of time. Because the subject may not always have the maximum time to get ready, essential activities should be placed near the end, to ensure the "minimal" set of activities is always performed. For example, brushing teeth.

❑ 4. Define chapter names for each morning activity.
Defining logical chapters will enable the subject to enter the morning activity at a different point in the routine if the desired 45 minute time period is not available due to special circumstances of the day. If possible, the 45, 30 and 15-minute chapters should be named as such, and other entry points may be named as desired. The chapter names from the bedtime routine from U1 can be used as an example.

❑ 5. Documentation of Phase 2a.
No electronic recording of the design sessions will be made. Each separate design session should be documented on the appropriate forms in a timely and accurate manner.

❑ 6. Repeating Phase 2a.
Because the subject is the primary designer, the activities of Phase 2a, 2b, and 3 may be repeated several times if the subject believes and the adult agrees it may not be "finished". The documentation should reflect each separate design cycle in its entirety.

3.5 Phase 2b

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 2b	N/A	N/A	*investigator as producer, fabricator of ambient media application designed by child (R2)*	N/A

Table 9. Overview of Phase 2b testing.

3.5.1 Required Materials

Digital camera photos.
Mac OS X
- iLife '04 (iPhoto, iMovie, iDVD)
- QuickTime
- Kinoma Producer

bedtime buddy DC (nbaCub)
PDA and external media card

3.5.2 Required Personnel and Roles

investigator as fabricator

3.5.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
[4] [29]	1-31-05 (M)	7-14	U2b	Fabricate new morning routine (R2) as a QuickTime, then Kinoma movie; Fabricate evaluation activities E3, E4, E5, E5 to test understanding of time passage and morning routine (R2)	A2c E3 E4 E5 E6

Table 10. Phase 2b Test plan, sample schedule.

3.5.4 Procedures

<u>U2b Fabrication of new ambient media and testing materials</u>.

- ❑ 1. Obtain complete design and materials from Phase 2a.
- ❑ 2. Fabricate an ambient media display representing the new routine, R2.
- ❑ 3. Create evaluation activities for Phase 3 and 4 post-testing.

3.6 Phase 3

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 3	designer director user tester	N/A	*child uses bedtime buddy display computer (nbaCub DC) to support new morning routine (R2) he designed/directed (c) [based on ambient media display (a)];* *usability testing U2*	understanding, learning of time passage and morning routine (R2); E3, E4

Table 11. Overview of Phase 3 testing.

3.6.1 Required Materials

bedtime buddy DC (nbaCub)
ambient media on external card
Kinoma movie (routine R2) (lightweight display (c))
PDA battery charger

3.6.2 Required Personnel and Roles

child subject as user, tester
parent/data gatherer as observer, evaluator

3.6.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
[6] [43]	2-14-05 (M)	All (14)	L3	Log morning routine activities and comments	L3-[43.. 56]
[6] [43]	2-14 (M)	5	U3	child uses DC to support morning routine (R2) with display (c)	A3a
[6] [48]	2-19 (Sa)	2		off (rest)	
[7] [50]	2-21 (M)	5	U3	child uses DC to support morning routine (R2) with display (c)	A3b
[7] [55]	2-26 (Sa)	1	Q3 Q4	Test concepts of time passage and morning routine (R2)	A3c A3d
[8] [56]	2-27 (Su)	1	E3 E4	Evaluation of understanding of time passage and morning routine	A3e A3f

Table 12. Phase 3 Test plan, sample schedule.

3.6.4 Procedures

U3 Morning Routine.

❑ 1. Specify target start time.
The target wake up time and target start time for the subject should be the same every morning. Since each day is always different, the actual start time to get ready in the morning may differ slightly. The best scenario is to allow the subject the maximum time (45 minutes) to get ready in the morning. The minimum time should be no less than 15 minutes. The third option is 30 minutes. The less time, the fewer routine activities the subject is expected to perform.

❑ 2. Select DC prototype nbaCub.
Hopefully the subject will select the nbaCub every morning on his own initiative. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around while getting ready.

❑ 3. Start lightweight display (c) on DC prototype nbaCub.
If the subject is able and interested, he should be able to start the lightweight display (with help if necessary). If less than the maximum time is available, the parent may wish to help the subject use the chapter feature to start the display at another increment.

❑ 4. Calculate target end time.
Target end time is actual start time plus the time selected for actual routine (45, 30, or 15 minutes).

❑ 5. Subject carries the nbaCub while embarking on a morning routine.
Hopefully the subject will carry around the nbaCub consistently while performing routine morning activities. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around until he finishes all his morning activities. The observer should unobtrusively keep tabs on the subject and his progress throughout the routine.

❑ 6. At target end time, subject and nbaCub should finished with the final activity.
Each lightweight display is actually 50 minutes long instead of 45 minutes. That gives the subject an extra minute or two if needed.

❑ 7. Documentation of morning's activities.
Observer should record the morning's observations on the appropriate forms as quickly and accurately as possible.

❑ 8. Charge up the battery of the nbaCub PDA.
At some point before the next use of the nbaCub by the subject, the PDA must be taken out and its battery recharged.

3.7 Phase 4

Testing	Role of Child	Pre-Test	Activity	Post-Test
Phase 4	user tester	N/A	child uses bedtime buddy display computer (DC) to support R1, R2; ambient media display of time passage only (b); no task image to-do list cues; usability testing U4	understanding, learning of time passage; bedtime (R1) and morning routine (R2); E5, E6

Table 13. Overview of Phase 4 Testing.

3.7.1 Required Materials

bedtime buddy DC (nbaCub)
ambient media on external card
Kinoma movie (time passage only) (figure 3, lightweight display (b))
PDA battery charger

3.7.2 Required Personnel and Roles

child subject as user, tester
parent/data gatherer as observer, evaluator

3.7.3 Sample Test Plan

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Docu menta tion
[8] [57]	2-28-05 (M)	All (14)	L4	Log all routine activities and comments [some test days will have 2 entries, one for morning, one for evening; label (a) and (b)]	L4-[57.. 69]
[8] [57]	2-28 (M)	5	U4	child uses nbaCub to support all routines (R1, R2) with display (b)	A4a1 A4a2
[8] [62]	3-5 (Sa)	2		off (rest)	
[9] [63]	3-7 (M)	5	U4	child uses nbaCub to support all routines (R1, R2) with display (b)	A4b1 A4b2
[9] [69]	3-12 (Sa)	1	Q1 Q2 Q3 Q4	Test concepts of time passage; morning routine (R2) and bedtime routine (R1)	A4c A4d A4e A4f
[9] [69]	3-12 (Sa)	1	E5, E6	Evaluation of understanding of time passage; morning routine (R2) and bedtime routine (R1)	A4g A4h

Table 14. Phase 4 Test plan, sample schedule.

3.7.4 Procedures

U4 Morning Routine.

❑ 1. Specify target start time.

The target wake up time and target start time for the subject should be the same every morning. Since each day is always different, the actual start time to get ready in the morning may differ slightly. The best scenario is to allow the subject the maximum time (45 minutes) to get ready in the morning. The minimum time should be no less than 15 minutes. The third option is 30 minutes. The less time, the fewer routine activities the subject is expected to perform.

❑ 2. Select DC prototype nbaCub.

Hopefully the subject will select the nbaCub every morning on his own initiative. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around while getting ready.

❑ 3. Start lightweight display (b) on DC prototype nbaCub.

If the subject is able and interested, he should be able to start the lightweight display (with help if necessary). If less than the maximum time is available, the parent may wish to help the subject use the chapter feature to start the display at another increment.

❑ 4. Calculate target end time.

Target end time is actual start time plus the time selected for actual routine (45, 30, or 15 minutes).

❑ 5. Subject carries the nbaCub while embarking on a morning routine.

Hopefully the subject will carry around the nbaCub consistently while performing routine morning activities. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around until he finishes all his morning activities. The observer should unobtrusively keep tabs on the subject and his progress throughout the routine.

❑ 6. At target end time, subject and nbaCub should finished with the final activity.

Each lightweight display is actually 50 minutes long instead of 45 minutes. (The final "dcWorld" image will be displayed for 5 minutes before the movie ends.) That gives the subject an extra minute or two if needed.

❑ 7. Documentation of morning's activities.

Observer should record the morning's observations on the appropriate forms as quickly and accurately as possible.

❑ 8. Charge up the battery of the nbaCub PDA.

At some point before the evening use of the nbaCub by the subject, the PDA must be taken out and its battery recharged.

U4 Evening Routine.

❑ 9. Specify target bedtime and target start time.
The target bedtime and target start time for the subject should be the same every evening. Since each day is always different, the actual start time to get ready for bed may differ slightly every evening. The best scenario is to allow the subject the maximum time (45 minutes) to get ready for bed. The minimum time should be no less than 15 minutes. The third option is 30 minutes. The less time, the fewer routine activities the subject is expected to perform.

❑ 10. Select DC prototype nbaCub.
Hopefully the subject will select the nbaCub every evening on his own initiative after one reminder that it is time to get ready for bed. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around before bedtime.

❑ 11. At target start time, start lightweight display (b) on DC prototype nbaCub.
If the subject is able and interested, he should be able to start the lightweight display at the appropriate target start time (with help if necessary). If less than the maximum time is available, the parent may wish to help the subject use the chapter feature to start the display at another increment.

❑ 12. Calculate target end time.
Target end time is actual start time plus the time selected for actual routine (45, 30, or 15 minutes).

❑ 13. Subject carries the nbaCub while embarking on a bedtime routine.
Hopefully the subject will carry around the nbaCub consistently while performing routine bedtime activities. If necessary, the parent may give the nbaCub to the subject and remind him to carry it around until he gets into bed. The observer should unobtrusively keep tabs on the subject and his progress throughout the routine.

❑ 14. At target end time, subject and nbaCub should be in bed!
Each lightweight display is actually 50 minutes long instead of 45 minutes. That gives the subject an extra minute or two if necessary, to get into bed. The parent(s) should also have a couple of minutes to tuck the subject in and say final "good nights" to the subject and nbaCub.

❑ 15. Documentation of evening's activities.
Observer should record the evening's observations on the appropriate forms as quickly and accurately as possible.

❑ 16. Charge up the battery of the nbaCub PDA.
At some point before the next morning use of the nbaCub by the subject, the PDA must be taken out and its battery recharged.

Figures 2 and 3

Figure 2. Table 1, Prototype lightweight display (a): to-do list on pie chart. Task images on pie slices in order of bedtime routine; overlay different pie slice on top of image every 5 min. (15 min. in this illustration) to show the time slice is up.

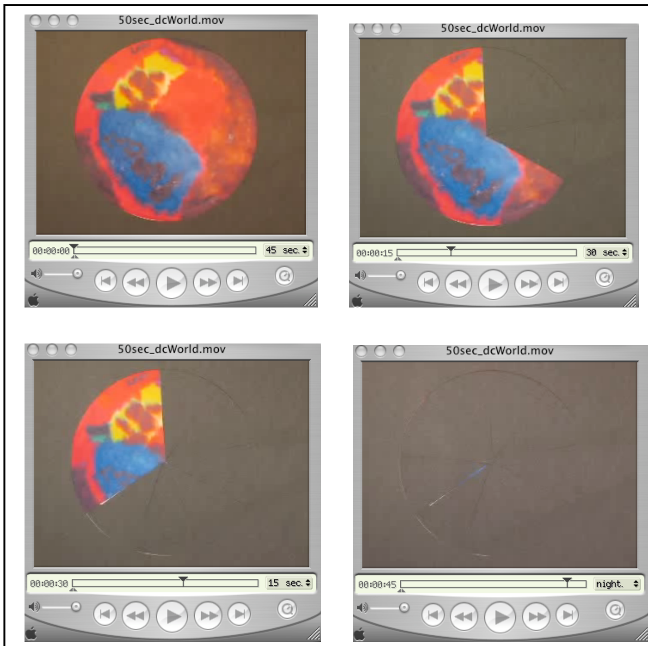

Figure 3. Table 1 (b). Prototype of dcWorld lightweight display showing time passage only. Illustrates four *chapters* from top left: start of timer shows full image of "dcWorld", after 15 min. (three 5-minute time-slices), 2/3rds of image remains; after 30 min., only 1/3 of image remains on display; after 45 min., final image is all dark…bedtime!

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APPENDIX B
ASSESSMENT INSTRUMENTS

Appendix B contains detailed Assessment Instruments used in the Display Computer Prototype field study of Section 5. The assessment instruments were submitted and approved as part of the IRB application, required documentation of the proposed human subjects research protocol by the Texas A&M University Institutional Review Board.

IRB Application: Assessment Instruments

Submitted to the Institutional Review Board of

Texas A&M University

Submitted by: Lisa M. Smith

November 2004

Child's Play:
A Display Computer Prototype Study

Assessment Instruments
Table of Contents

1 Sample Test Plan, Phases 1-4

Note: This is just an example of how the 10-week testing with the child subject would progress if everything went as planned. The dates of the four phases can and will be adjusted if circumstances require.

Start week and day	Actual Date (ex.)	No. of days	Te st ID	Activity	Documentation ID
[0] [1]	1-3-05 (M)	all (20)	L1	Log bedtime routine activities and comments	L1-[1..20]
[0] [6]	1-8 (Sa)	1	Q1	Test concepts of time passage and bedtime routine (R1)	A1a
[0] [7]	1-9 (Su)	1		off (rest)	
[1] [8]	1-10 (M)	5	U1	child uses nbaCub to support bedtime routine (R1) with display (a)	A1b
[1] [13]	1-15 (Sa)	2		off (rest)	
[2] [15]	1-17 (M)	5	U1	child uses nbaCub to support bedtime routine (R1) with display (a)	A1c
[2] [20]	1-22 (Sa)	1	Q1 Q2	Test concepts of time passage and bedtime routine (R1)	A1d A1e
[2] [20]	1-22 (Sa)	1	E1 E2	Evaluation of understanding of time passage and bedtime routine	A1f A1g
[3] [21]	1-23-05 (Su)	All (22)	L2	Log morning routine activities and comments	L2-[21..42]
[3] [21]	1-23 (Su)	1	Q3	Test concepts of time passage and morning routine (R2)	A2a
[3] [22]	1-24 (M)	7	U2 D1	design session(s) of new ambient media display (c)	A2b D1-[1..x]
[4] [29]	1-31 (M)	7	[U2] [D2]	off, if task completed, or continue design sessions	[A2b [1..x]] D2-[1..x]
[4] [29]	1-31-05 (M)	7-14	U2b	Fabricate new morning routine (R2) as a QuickTime, then Kinoma movie; Fabricate evaluation activities E3, E4, E5, E5 to test understanding of time passage and morning routine (R2)	A2c E3 E4 E5 E6
[7] [43]	2-14-05 (M)	All (14)	L3	Log morning routine activities and comments	L3-[43..56]
[7] [43]	2-14 (M)	5	U3	child uses nbaCub to support morning routine (R2) with display (c)	A3a
[7] [48]	2-19 (Sa)	2		off (rest)	
[8] [50]	2-21 (M)	5	U3	child uses nbaCub to support morning routine (R2) with display (c)	A3b
[8] [55]	2-26 (Sa)	1	Q3 Q4	Test concepts of time passage and morning routine (R2)	A3c A3d
[8] [56]	2-27 (Su)	1	E3 E4	Evaluation of understanding of time passage and morning routine	A3e A3f
[8] [57]	2-28-05 (M)	All (14)	L4	Log all routine activities and comments [some test days will have 2 entries, one for morning, one for evening; label (a) and (b)]	L4-[57..70]
[8] [57]	2-28 (M)	5	U4	child uses nbaCub to support all routines (R1, R2) with display (b)	A4a1 A4a2
[8] [62]	3-5 (Sa)	2		off (rest)	
[9] [63]	3-7 (M)	5	U4	child uses nbaCub to support all routines (R1, R2) with display (b)	A4b1 A4b2
[9] [69]	3-12 (Sa)	1	Q1 Q2 Q3 Q4	Test concepts of time passage; morning routine (R2) and bedtime routine (R1)	A4c A4d A4e A4f
[10] [70]	3-13 (Su)	1	E5, E6	Evaluation of understanding of time passage; morning routine (R2) and bedtime routine (R1)	A4g A4h

2 Sample Calendars

Note: This is a Sample Calendar by Test ID of how testing would progress if everything went as planned. The dates of the testing phases can and will be adjusted if circumstances require.

Week	Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		12/12/04	12/13/04	12/14/04	12/15/04	12/16/04	12/17/04	12/18/04
		12/19/04	12/20/04	12/21/04	12/22/04	12/23/04	12/24/04	12/25/04
			Phase 0a **U0**		**Phase 0b** U0b			
		12/26/04	12/27/04	12/28/04	12/29/04	12/30/04	12/31/04	1/1/05
Week	Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
0	0	1/2/05	1/3/05	1/4/05	1/5/05	1/6/05	1/7/05	1/8/05
			L1 **Phase 1**	L1	L1	L1	L1	L1 Q1
1	7	1/9/05	1/10/05	1/11/05	1/12/05	1/13/05	1/14/05	1/15/05
		L1 off	L1 U1	L1 U1	L1 U1	L1 U1	L1 U1	L1 rest
2	14	1/16/05	1/17/05	1/18/05	1/19/05	1/20/05	1/21/05	1/22/05
		L1 rest	L1 U1	L1 U1	L1 U1	L1 U1	L1 U1	L1 Q1-2,E1-2
3	21	1/23/05	1/24/05	1/25/05	1/26/05	1/27/05	1/28/05	1/29/05
		Phase 2a L2, Q3	L2 U2, D1	L2 U2, D1	L2 U2, D1	L2 U2, D1	L2 U2, D1	L2 U2, D1
4	28	1/30/05	1/31/05	2/1/05	2/2/05	2/3/05	2/4/05	2/5/05
		L2 U2, D1	L2 U2,D2|U2b	L2 U2,D2|U2b	L2 U2,D2|U2b	L2 U2,D2|U2b	L2 U2,D2|U2b	L2 U2,D2|U2b
5	35	2/6/05	2/7/05	2/8/05	2/9/05	2/10/05	2/11/05	2/12/05
		L2-35 U2,D2|U2b	**Phase2b** L2b, U2b	L2 U2b	L2 U2b	L2 U2b	L2 U2b	L2 U2b
6	42	2/13/05	2/14/05	2/15/05	2/16/05	2/17/05	2/18/05	2/19/05
		L2 U2b	**Phase 3** L3, U3	L3 U3	L3 U3	L3 U3	L3 U3	L3 rest
7	49	2/20/05	2/21/05	2/22/05	2/23/05	2/24/05	2/25/05	2/26/05
		L3 rest	L3 U3	L3 U3	L3 U3	L3 U3	L3 U3	L3 Q3, Q4
8	56	2/27/05	2/28/05	3/1/05	3/2/05	3/3/05	3/4/05	3/5/05
		L3 E3, E4	**Phase 4** L4, U4	L4 U4	L4 U4	L4 U4	L4 U4	L4 rest
9	63	3/6/05	3/7/05	3/8/05	3/9/05	3/10/05	3/11/05	3/12/05
		L4 rest	L4 U4	L4 U4	L4 U4	L4 U4	L4 U4	L4 Q1-4
10	70	3/13/05	3/14/05	3/15/05	3/16/05	3/17/05	3/18/05	3/19/05
		L4 E5-E6						

Note: This is a Sample Calendar by Documentation ID of how testing would progress if everything went as planned. The dates of the testing phases can and will be adjusted if circumstances require.

Week	Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		12/12/04	12/13/04	12/14/04	12/15/04	12/16/04	12/17/04	12/18/04
		12/19/04	12/20/04	12/21/04	12/22/04	12/23/04	12/24/04	12/25/04
			Phase 0a **A0**		**Phase 0b** A0b			
		12/26/04	12/27/04	12/28/04	12/29/04	12/30/04	12/31/04	1/1/05

Week	Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
0	0	1/2/05	1/3/05	1/4/05	1/5/05	1/6/05	1/7/05	1/8/05
			Phase 1 L1-1	L1-2	L1-3	L1-4	L1-5	L1-6 A1a
1	7	1/9/05	1/10/05	1/11/05	1/12/05	1/13/05	1/14/05	1/15/05
		L1-7 off	L1-8 A1b	L1-9 A1b	L1-10 A1b	L1-11 A1b	L1-12 A1b	L1-13 rest
2	14	1/16/05	1/17/05	1/18/05	1/19/05	1/20/05	1/21/05	1/22/05
		L1-14 rest	L1-15 A1c	L1-16 A1c	L1-17 A1c	L1-19 A1c	L1-19 A1c	L1-20 A1d-A1g
3	21	1/23/05	1/24/05	1/25/05	1/26/05	1/27/05	1/28/05	1/29/05
		Phase 2a L2-21,A2a	L2-22 A2b, D1-1	L2-23 A2b, D1-x	L2-24 A2b, D1-x	L2-25 A2b, D1-x	L2-26 A2b, D1-x	L2-27 A2b, D1-x
4	28	1/30/05	1/31/05	2/1/05	2/2/05	2/3/05	2/4/05	2/5/05
		L2-28 A2b, D1-x	L2-29 A2b | A2c	L2-30 A2b | A2c	L2-31 A2b | A2c	L2-32 A2b | A2c	L2-33 A2b | A2c	L2-34 A2b | A2c
5	35	2/6/05	2/7/05	2/8/05	2/9/05	2/10/05	2/11/05	2/12/05
		L2-35 A2b | A2c	**Phase 2b** L2-36, A2c	L2-37 A2c	L2-38 A2c	L2-39 A2c	L2-40 A2c	L2-41 A2c
6	42	2/13/05	2/14/05	2/15/05	2/16/05	2/17/05	2/18/05	2/19/05
		L2-42 A2c, E3-E6	**Phase 3** L3-43,A3a	L3-44 A3a	L3-45 A3a	L3-46 A3a	L3-47 A3a	L3-48 rest
7	49	2/20/05	2/21/05	2/22/05	2/23/05	2/24/05	2/25/05	2/26/05
		L3-49 rest	L3-50 A3b	L3-51 A3b	L3-52 A3b	L3-53 A3b	L3-54 A3b	L3-55 A3c,A3d
8	56	2/27/05	2/28/05	3/1/05	3/2/05	3/3/05	3/4/05	3/5/05
		L3-56 A3e,A3e	**Phase 4** L4-57,A4a	L4-58a,b A4a1,2	L4-59a,b A4a1,2	L4-60a,b A4a1,2	L4-61a,b A4a1,2	L4-62a,b rest
9	63	3/6/05	3/7/05	3/8/05	3/9/05	3/10/05	3/11/05	3/12/05
		L4-63a,b rest	L4-64a,b A4b1,2	L4-65a,b A4b1,2	L4-66a.b A4b1,2	L4-67a,b A4b1,2	L4-68a,b A4b1,2	L4-69a,b A4c-f
10	70	3/13/05	3/14/05	3/15/05	3/16/05	3/17/05	3/18/05	3/19/05
		L4-70a,b A4g-A4h						

3 Documentation Forms

A workbook of these documentation forms will be given to the parent/data gatherer as an assessment instrument to record the research study observations on a daily basis. The sample test plan and calendars can be used as a guide to access to the appropriate forms for each phase in sequential order by week and day of study.

3.1 Observation Logs

The child subject will be observed each day of the field study by at least one adult (his or her parent in the role of data gatherer). The purpose is to get an idea of what the subject's daily routines in question are; before, during and after the use of the nbaCub Display Computer prototype. Thus, for Phases 1 and 4, an observation log should be filled out during the bedtime routine. For Phases 2, 3, and 4, an observation log should be filled out during the morning routine.

3.1.1 Instructions

The parent/data gatherer should observe the child subject during the daily bedtime and/or morning routine in an unobtrusive manner, as much as possible.

3.1.2 Sample Form

For item (4a) ambient media used, use the following table as reference.

type	**lightweight display**
a	***ambient nighttime routine with time*** *passage*
b	***ambient time passage***
c	***ambient morning routine with time passage***

3.1.2.1 L1, L2, L3, L4

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

L[1 2 3 4]-[___]{a,b, } **Daily Observation Log**

(1) *nbaCub selected by*: subject parent other_________ <not used>
(1a) *if subject…* time: _____ min. # reminders: ___

(2) *nbaCub carried as needed*: Yes Most Some Start only No <n/a>

(3a) *Target Start time*: _____ *Target End Time*:________ <n/a>
(3b) *Actual Start time*: _____ *Actual End time*: _______ <n/a>

(4a) *Ambient Media Used*: a b c <n/a>
(4b) *Started by*: subject parent other____________ <n/a>
(4c) *Chapter Use*: Yes[chapter ____________] No <n/a>

(6) *Observed routine*:

Activity	*Time (minutes)*	*Activity*	*Time (minutes)*

(7) *Subject's comments (about nbaCub or routine)*:

(8) *Other observations*:

(9) *The nbaCub seemed to be*: Very helpful
Somewhat helpful
Not helpful
Other:____________________ <n/a>

Recorded by: Date/Time Recorded:

3.2 Questionnaires

The purpose of the questionnaires is to provide a pre- and post-test measure of the before and after knowledge and understanding of the abstract concepts of "time passage" and "routine" by the child, before and following the use of the nbaCub Display Computer prototype.

3.2.1 Instructions

Each questionnaire will include a simple list of open-ended questions. The data gatherer should engage the subject in an informal conversation on the designated testing date. The data gatherer should record the subject's response on the form verbatim, as much as possible. No electronic recording devices will be used.

3.2.2 Sample Questions

3.2.2.1 Q1

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q1 Phase 1 Questionnaire 1

A1a Phase 1 Pre-Testing

(1) How do you know when it is time to get ready for bed?

(2) How long does it take you to get ready for bed?

(3) What do you need to do to get ready for bed?

(4) How do you know when it is time to go to bed?

Recorded by: Date/Time Recorded:

Routine: Bedtime	*Date*:______		*Week*:____	Phase: 1 2 3 4
Morning	*Time*:______	am pm	*Day*: ____	pre test post rest

Q1 **Phase 1 Questionnaire 1**

A1d **Phase 1 Post-Testing**

(1) How do you know when it is time to get ready for bed?

(2) How long does it take you to get ready for bed?

(3) What do you need to do to get ready for bed?

(4) How do you know when it is time to go to bed?

Recorded by: Date/Time Recorded:

Routine: Bedtime Morning	*Date*:______ *Time*:______ am pm	*Week*:____ *Day*: ____	Phase: 1 2 3 4 pre test post rest

Q1 Phase 4 Questionnaire 1

A4c Phase 4 Post-Testing

(1) How do you know when it is time to get ready for bed?

(2) How long does it take you to get ready for bed?

(3) What do you need to do to get ready for bed?

(4) How do you know when it is time to go to bed?

Recorded by: Date/Time Recorded:

3.2.2.2 Q2

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q2 Phase 1 Questionnaire 2

A1e Phase 1 Post-Testing

Note: These questions will be modified to fit the subject's DC.

(1) What did you like best about the leopard cub?

(2) Did he help you get ready for bed? How?

(3) If you could change any of the pictures, what would you change?

(4) What are some other things the leopard cub help you with, other than getting ready for bed?

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q2 Phase 4 Questionnaire 2

A4d Phase 4 Post-Testing

Note: These questions will be modified to fit the subject's DC.

(1) What did you like best about the leopard cub?

(2) Did he help you get ready for bed? How?

(3) If you could change any of the pictures, what would you change?

(4) What are some other things the leopard cub help you with, other than getting ready for bed?

Recorded by: Date/Time Recorded:

3.2.2.3 Q3

Routine: Bedtime Morning	*Date*:______ *Time*:______ am pm	*Week*:____ *Day*: ____	Phase: 1 2 3 4 pre test post rest

Q3 Phase 2 Questionnaire 1

A2a Phase 2 Pre-Testing

(1) How do you know when it is time to get up in the morning?

(2) How long does it take you to get ready to leave the house in the morning?

(3) What do you need to do to get ready to leave the house in the morning?

(4) What do you need help with when you get ready in the morning?

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q3 **Phase 3 Questionnaire 1**

A3c **Phase 3 Post-Testing**

(1)How do you know when it is time to get up in the morning?

(2)How long does it take you to get ready to leave the house in the morning?

(3)What do you need to do to get ready to leave the house in the morning?

(4)What do you need help with when you get ready in the morning?

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q3 Phase 4 Questionnaire 3

A4e Phase 4 Post-Testing

(1) How do you know when it is time to get up in the morning?

(2) How long does it take you to get ready to leave the house in the morning?

(3) What do you need to do to get ready to leave the house in the morning?

(4) What do you need help with when you get ready in the morning?

Recorded by: Date/Time Recorded:

3.2.2.4 Q4

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

Q4 Phase 3 Questionnaire 2

A3d Phase 3 Post-Testing

Note: These questions will be modified to fit the subject's DC.

(1) What did you like best about the leopard cub?

(2) Did he help you get ready in the morning? How?

(3) If you could change anything about your movie, what would you change?

(4) What are some other things the leopard cub help you with, other than getting ready in the morning and getting ready for bed?

Recorded by: Date/Time Recorded:

Routine:	Bedtime	*Date*:______		*Week*:____	Phase: 1 2 3 4
	Morning	*Time*:______	am pm	*Day*: ____	pre test post rest

Q4 Phase 4 Questionnaire 4

A4f Phase 4 Post-Testing

Note: These questions will be modified to fit the subject's DC.

(1)What did you like best about the leopard cub?

(2)Did he help you get ready in the morning? How?

(3)If you could change anything about your movie, what would you change?

(4)What are some other things the leopard cub help you with, other than getting ready in the morning and getting ready for bed?

Recorded by: Date/Time Recorded:

3.3 Usability Testing

Usability testing refers to the actual testing activity in each phase of the study. For example, in Phases 1, 3, and 4, the actual testing activity is having the subject "use" the nbaCub to support his daily routine(s). In Phase 2a, the testing activity is the Test by Design session(s) where the subject is the primary designer or director. In Phase 2b, the primary activity is the fabrication of the design resulting from Phase 2a. Phases 0a and 0b are similar to Phase 2, except the parent plays the primary designer and director roles, while the child subject has not role yet.

3.3.1 Instructions

In Phase 0a, the outcome of the design sessions should be a personalized bedtime routine (R1) for the target user: the child subject. The complete specifications of routine activities, digital photographs, and specific 45-minute timeline will be used in Phase 0b to fabricate the actual lightweight ambient media for use on the nbaCub. The physical form factor of the bedtime buddy will be chosen by the child subject in Phase 0a, and modified into a DC prototype in Phase 0b.

In Phases 1, 3, and 4 of usability testing, the five-day summary forms should be filled out on a daily basis from the appropriate daily observation forms (L1, L3, L4). At the end of the week, a brief summary of the highlights and an overview of the testing activity should be provided on the back of the forms.

In Phase 2a, the summary sheet of the design sessions (one per design cycle) should be filled out on a per meeting basis from the appropriate design log form (D1). The completion of all design meetings should result in a personalized morning routine (R2) specification of routine activities, digital photographs, and specific 45-minute timeline. These specifications will be used in Phase 2b. A brief summary of the highlights and an overview of the Test by Design phase should be provided on the back of the form. Note that two sets of forms are provided should more than one design cycle be required to complete the task.

For Phase 2b, a checklist is provided which outlines the major steps needed to fabricate the ambient media specified in Phase 2a. The fabricator should log the time needed for each activity as well as important notes. Again, a brief summary should be provided on the back of the form that provides an overview of how this phase of the study progressed.

3.3.2 Sample Forms

3.3.2.1 U0

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U0 Design of personal bedtime routine R1
A0a Phase 0a

(1) *Design meetings:*

	Date	*Time start*	*Form Number Description of Activity*	*Time end*	*Total time*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

(2) *Newly personalized bedtime routine:*

Routine activity Description	*Timing (total 50 min.)*	*Chapters (45, 30, 15, ready!)*	*Original media type*	*Digital photo*

(3) *Overall summary of this design (record on back).*

Recorded by: Date/Time Recorded:

3.3.2.2 U0b

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U0b **Fabrication of Ambient Media (a)**
A0b **Phase 0b**

(1) *Start Date/Time:*
(2) *End Date/Time:*
(3) *Total Time:*

(4) *Checklist:*

	Activity	**Start time**	**End time**	**Total time**
1	Obtain final complete design of subject's personalized bedtime routine (R1).			
2	Obtain digital photos for routine activities.			
3	Import digital photos into iPhoto. Print.			
4	Create 10 images of a "morning" to "night" clock using portions of the digital photos of the routine tasks and the timeline defined by subject.			
5	Design an iMovie using the 10 images (display changes for each 5 minute increment) and design specifications. Ambient time should move from light to dark (simulating waking up in the morning). Add chapter definitions.			
6	Convert QuickTime movie into Kinoma movie.			
7	Load Kinoma movie onto external media card.			
8	Design evaluation activities E1 and E2 using still digital photos.			

(5) *Notes (continue on additional sheets as necessary):*

(6) *Overall summary of Phase 0b (record on back).*

Recorded by: Date/Time Recorded:

3.3.2.3 U1

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U1 Usability Testing Summary
A1b Phase 1 Week 1 (evenings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther______ (N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther___________
(4c) chapters used: yes, no

day	1a	1b	1c	2a	2b	2c	3a	3b	4a	4b	4c
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U1 Usability Testing Summary
A1c Phase 1 Week 2 (evenings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther______ (N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther_________
(4c) chapters used: yes, no

day	1a	1b	1c	2a	2b	2c	3a	3b	4a	4b	4c
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

3.3.2.4 U2

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U2 Test by Design Session Summary 1
A2b Phase 2a

(1a) *Design meetings:*

	Date	*Time start*	*Form Number Description of Activity*	*Time end*	*Total time*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

(1b) For each meeting, fill out a design log form (**D1-**[1..x]).

(2) *Newly defined morning routine:*

Routine activity Description	*Timing (total 50 min.)*	*Chapters (45, 30, 15, ready!)*	*Original media type*	*Digital photo*

(3) *Overall summary of this design cycle (record on back).*

Recorded by: Date/Time Recorded:

3.3.2.4.1 D1

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

D[1 2]-[__] **Design Session Log (Phase 2a)**

(1) Start Time:
(2) End Time:
(3) Total Time:
(4) Total Participants: ______
(5) Roles: (S)ubject (P)arent/Data Gatherer
(I)nvestigator (O)ther_______________

(6)Activities and Participants:

Design Activity (including breaks)	*Time (min.)*	*Partici pants*

(7) *Subject's comments*:

(8) *Other observations*:

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U2 **Test by Design Session Summary 2**
A2b1 **Phase 2a**

(1a) *Design meetings:*

	Date	*Time start*	*Form Number Description of Activity*	*Time end*	*Total time*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

(1b) For each meeting, fill out a design log form (**D2-**[1..x]).

(2) *Newly defined morning routine:*

Routine activity Description	*Timing (total 50 min.)*	*Chapters (45, 30, 15, ready!)*	*Original media type*	*Digital photo*

(3) *Overall summary of this design cycle (record on back).*

Recorded by: Date/Time Recorded:

3.3.2.4.2 D2

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

D[1 2]-[__] Design Session Log (Phase 2a)

(1)Start Time:
(2)End Time:
(3)Total Time:
(4)Total Participants: ______
(5)Roles: (S)ubject (P)arent/Data Gatherer
(I)nvestigator (O)ther_______________

(6)Activities and Participants:

Design Activity (including breaks)	*Time (min.)*	*Partici pants*

(7) *Subject's comments*:

(8) *Other observations*:

Recorded by: Date/Time Recorded:

3.3.2.5 U2b

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U2b **Fabrication of Ambient Media (c)**
A2c **Phase 2b**

(1) *Start Date/Time:*
(2) *End Date/Time:*
(3) *Total Time:*

(4) *Checklist:*

	Activity	**Start time**	**End time**	**Total time**
1	Obtain final complete design of subject's personalized morning routine (R2).			
2	Obtain digital photos for routine activities.			
3	Import digital photos into iPhoto. Print.			
4	Create 10 images of a "night" to "morning" clock using portions of the digital photos of the routine tasks and the timeline defined by subject.			
5	Design an iMovie using the 10 images (display changes for each 5 minute increment) and design specifications. Ambient time should move from dark to light (simulating waking up in the morning). Add chapter definitions.			
6	Convert QuickTime movie into Kinoma movie.			
7	Load Kinoma movie onto external media card.			
8	Design evaluation activities E3, E4, E5, and E6 using still digital photos.			

(5) *Notes (continue on additional sheets as necessary):*

(6) *Overall summary of Phase 2b (record on back).*

Recorded by: Date/Time Recorded:

3.3.2.6 U3

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U3 Usability Testing Summary
A3a Phase 3 Week 1 (mornings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther______ (N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther___________
(4c) chapters used: yes, no

day	1a	1b	1c	2a	2b	2c	3a	3b	4a	4b	4c
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week’s usability study (record on back).

Recorded by: Date/Time Recorded:

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U3 Usability Testing Summary
A3b Phase 3 Week 2 (mornings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther______(N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther___________
(4c) chapters used: yes, no

day	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**3a**	**3b**	**4a**	**4b**	**4c**
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

3.3.2.7 U4

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

U4 Usability Testing Summary
A4a1 Phase 4 Week 1 (mornings)

(1a) nbaCub selected by: (S)ubject (P)arent (O)ther______ (N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a) nbaCub carried as needed: yes, most, some
(2b) nbaCub carried at start only
(2c) nbaCub not carried by subject

(3a) Difference between target and actual start time (in minutes)
(3b) Difference between target and actual end time (in minutes)

(4a) Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther____________
(4c) chapters used: yes, no

day	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**3a**	**3b**	**3c**	**4a**	**4b**	**4c**
1 M												
2 T												
3 W												
4 R												
5 F												

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

Routine: Bedtime   *Date*:______   *Week*:____   Phase: 1 2 3 4
Morning   *Time*:______ am pm   *Day*: ____   pre test post rest

U4 Usability Testing Summary
A4a2 Phase 4 Week 1 (evenings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther_______(N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther___________
(4c) chapters used: yes, no

day	1a	1b	1c	2a	2b	2c	3a	3b	4a	4b	4c
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

Routine: Bedtime	*Date*:______	*Week*:____	Phase: 1 2 3 4
Morning	*Time*:______ am pm	*Day*: ____	pre test post rest

U4 Usability Testing Summary
A4b1 Phase 4 Week 2 (mornings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther_______(N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther_____________
(4c) chapters used: yes, no

day	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**3a**	**3b**	**4a**	**4b**	**4c**
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6)Overall summary of week's usability study (record on back).

Recorded by: Date/Time Recorded:

Routine: Bedtime   *Date*:______   *Week*:____   Phase: 1 2 3 4
Morning   *Time*:______ am pm   *Day*: ____   pre test post rest

U4 Usability Testing Summary
A4b2 Phase 4 Week 2 (evenings)

(1a)nbaCub selected by: (S)ubject (P)arent (O)ther_______(N)ot used
(1b) if subject, time in minutes
(1c) if subject, number of reminders

(2a)nbaCub carried as needed: yes, most, some
(2b)nbaCub carried at start only
(2c)nbaCub not carried by subject

(3a)Difference between target and actual start time (in minutes)
(3b)Difference between target and actual end time (in minutes)

(4a)Ambient media used: (a) (b) (c)
(4b) started by: (S)ubject (P)arent (O)ther__________
(4c) chapters used: yes, no

day	**1a**	**1b**	**1c**	**2a**	**2b**	**2c**	**3a**	**3b**	**4a**	**4b**	**4c**
1 M											
2 T											
3 W											
4 R											
5 F											

(5) *Observed routine*:

Activity List	*Number of days(1-5)*	*Average time (total/days)*

(6) Overall summary of week’s usability study (record on back).

Recorded by: Date/Time Recorded:

3.4 Evaluation Activities

The purpose of the evaluation activity is to provide a post-test measure of the subject's understanding of the two abstract concepts (passage of time, routine) following the use of the nbaCub DC prototype and ambient media application(s).

3.4.1 Instructions

The subject should not be placed in a formal testing environment. Like the questionnaires, these evaluation activities are meant to be informal in nature. The subject should be given as much time as needed for each activity. The test sessions will not be recorded electronically.

An example is given for activities E1 and E2. These activities will be modified to fit the actual ambient media designed in Phase 0a. Note that activities E3, E4, E5, and E6 should follow the same examples, are not as yet defined. These will be designed in Phase 2b, after the morning routine R2 has been designed by the subject and fabricated by the investigator. They should follow the two basic types of evaluation activities: (1) show the subject some scenes taken from the lightweight displays and ask him simple questions based on the photos, or (2) ask the subject to demonstrate a simple task, such as ordering a to-do list using a set of flashcards illustrated with ambient media elements.

3.4.2 Sample Activities

3.4.2.1 E1

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

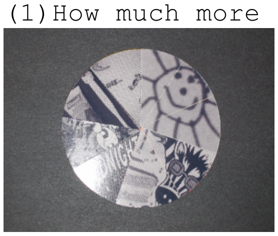
E1 Phase 1 Evaluation Activity 1

A1f Phase 1 Post-Testing

<This is an example. To be developed in Phase 0b.>

Activity: Show the subject the following (actual) photographs. After each one, ask him the associated question, and record his answer in the space to the right of the photo.

(1)How much more time do you have to get ready for bed?



Sample answer: zero, should be in bed.

(2)How much time do you have to get ready for bed?

Sample answer: 45 minutes, or list of activities.

(3) What is your next activity, after your free time is up?

Sample answer: snack time

(4) What do you do after you finish story time before you go to bed?

Sample answer: put on pajamas, brush teeth

Recorded by: Date/Time Recorded:

3.4.2.2 E2

Routine: Bedtime *Date*:_______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:_______ am pm *Day*: ____ pre test post rest

E2 Phase 1 Evaluation Activity 2

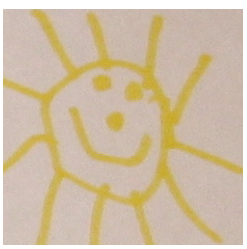
A1g Phase 1 Post-Testing

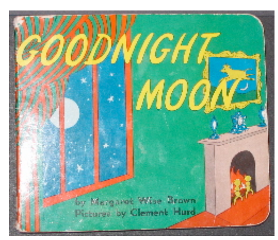
<This is an example. To be developed in Phase 0b.>

Activity:

Present the following flashcards denoting activities from lightweight display (a) to the subject in a random order (e.g. 6,1,4,5,3,2), one at a time. Ask the subject to place them in the correct order (uses an insertion sort) of the bedtime routine (R1). Allow the subject as much time as he needs, and as many tries as he needs to finish the task correctly.

Correct answer (left to right, top to bottom):
(1) Sun… free time
(2) Zebra cakes… snack time
(3) Goodnight moon book… bedtime story
(4) Powerpuff girl pajamas… change into pajamas
(5) Toothbrush and toothpaste… brush teeth
(6) nbaCub and pillow… get into bed!





Subject's ordering (continue on back of sheet, if necessary):

Try 1: ____ _____ _____ _____ _____ ____

Try 2: ____ _____ _____ _____ _____ ____

Recorded by: Date/Time Recorded:

3.4.2.3 E3

Routine: Bedtime	*Date*:______		*Week*:____	Phase: 1 2 3 4
Morning	*Time*:______	am pm	*Day*: ____	pre test post rest

E3 Phase 3 Evaluation Activity 1

A3e Phase 3 Post-Testing

<To be developed in Phase 2b.>

Recorded by: Date/Time Recorded:

3.4.2.4 E4

Routine: Bedtime *Date*:______ *Week*:____ Phase: 1 2 3 4
Morning *Time*:______ am pm *Day*: ____ pre test post rest

E4 Phase 3 Evaluation Activity 2

A3f Phase 3 Post-Testing

<To be developed in Phase 2b.>

Recorded by: Date/Time Recorded:

3.4.2.5 E5

Routine: Bedtime	*Date*:______		*Week*:____	Phase: 1 2 3 4
Morning	*Time*:______	am pm	*Day*: ____	pre test post rest

E5 Phase 4 Evaluation Activity 1

A4g Phase 4 Post-Testing

<To be developed in Phase 2b.>

Recorded by: Date/Time Recorded:

3.4.2.6 E6

Routine: Bedtime	*Date*:______	*Week*:____	Phase: 1 2 3 4
Morning	*Time*:______ am pm	*Day*: ____	pre test post rest

E6 **Phase 4 Evaluation Activity 2**

A4h **Phase 4 Post-Testing**

<To be developed in Phase 2b.>

Recorded by: Date/Time Recorded:

APPENDIX C
CONSENT FORM

Appendix C contains a copy of the Consent Form signed by the parent of the child subject selected for the Display Computer Prototype field study of Section 5. The consent form and information sheet were submitted and approved as part of the IRB application, required documentation of the proposed human subjects research protocol by the Texas A&M University Institutional Review Board.

CONSENT FORM

Child's Play: A Display Computer Prototype Study

I have been asked to participate in a research study to test the usability of the nbaCub (nightly bedtime ambient Cues utility buddy), a Display Computer (DC) prototype in my natural home setting. This study is part of Lisa M. Smith's doctoral research at Texas A&M University, and has been approved by her graduate committee in the Computer Science department. The results of this study will be published in her dissertation entitled "Display Computers" and the results may be published in a conference paper.

I was selected to be a possible participant because I have a kindergarten-aged child who has been identified as a possible subject for the study. A total of two people (myself and my child) have been asked to participate in this study. The purpose of this study is to observe and evaluate the use of the DC prototype as a novel and practical toy-and-tool-in-one -- the nbaCub provides a novel way to display lightweight, ambient information to kindergarten-aged children through a familiar "buddy" willing to accompany them as they go about performing the necessary daily routines of preparing for bed (evening routine), and preparing to go to school (morning routine).

If I agree to be in this study, I will be asked to participate as a data gatherer to observe my child's interaction with the nbaCub in a 10-week study in our home environment. I understand that one goal of this study is to "observe process or technology in situ, disturbing the system we observe as little as possible". Detailed test plans, calendars, and procedures will be provided as a guide or roadmap for the long-term study. In addition, a workbook will be provided so I can document the participation of my child in this study through daily written logs, and periodic questionnaires and evaluation activities. Prior to the 10-week study, I will participate with the investigator to design a personalized nbaCub DC prototype specifically customized to my child's interests and current bedtime routine, for my child's use during the study. This study will take approximately 11 weeks of my time. Each of the five phases differ, but the total time requirement should be no more than one or two hours per day for myself to take part in observation and documentation, and less than one hour per day of my child's time for usability of the nbaCub. During the "Test by Design" phase, the time requirement will increase on a short-term basis for both myself, and my child on a schedule of our own choosing.

If I agree for my child to be in this study, he/she will be given access to the nbaCub DC toy prototype in our home environment. A lightweight information display will appear on the nbaCub's shirt each evening before bedtime. My child will then participate in a Test by Design activity that I will facilitate, to design and direct a lightweight display of a morning routine. This visualization will combine both concepts of "time passage" and "routines" (to-do list task images) and will be used for the lightweight display in the next phase of usability testing. In final testing, an ambient media display that only visualizes time passage will be used.

There are no discomforts or risks associated with this study. The will be no monetary compensation for our participation in this study. The benefits for my child from the use of the nbaCub may be to learn, practice and begin to understand abstract concepts such as time and routines. Visual cues presented step-by-step in real-time, can help with the visualization and understanding of time passage and the "to-do list" required to perform routine activities. By the end of the 10-week study, my child may be able to generalize these concepts to other everyday routine activities, thereby only requiring the nbaCub to help out with time visualization (no task list). However, there may be no direct benefit from participating in this study.

This study is confidential. The records of this study will be kept private. No identifiers linking me to the study will be included in any sort of report that might be published. Research records will be stored securely and only Lisa M. Smith (the investigator), and Dr. John J. Leggett (faculty advisor) will have access to the records. My decision whether or not to participate will not affect my current or future relations with Texas A&M University. If I decide to participate, I am free to refuse to answer any of the questions that may make me uncomfortable. I can withdraw at any time with out my relations with the university, job, benefits, etc., being affected. I understand the investigator has ethical and legal obligations to report suspected child abuse or neglect to the proper authorities.

I can contact the investigator and/or faculty advisor (listed below) with any questions about the study.

Lisa M. Smith (Principal Investigator)
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Texas A&M University
College Station, TX 77843
Phone:
E-mail:

Dr. John J. Leggett (Faculty Advisor)
404 H.R. Bright Building
Texas A&M University
College Station, TX 77843
Phone:
E-mail:

This research study has been reviewed by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, I can contact the Institutional Review Board through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (mbuckley@tamu.edu).

I have been given a separate information sheet that provides a brief introduction of Display Computers; including motivation, definition, and the nbaCub leopard cub prototype. In addition, it contains a brief summary of the purpose, hypothesis, and overview of this study.

I have read the above information and understand the explanation provided to me. I have had all my questions answered to my satisfaction. By signing this document, I voluntarily agree to participate in this study, and I voluntarily agree to the participation of my child in this study. I have been given a copy of this consent form for my records.

Name of Child (print):________________________________

Signature:____ Date:_____________

Signature of Investigator:______________________________ Date:_____________

VITA

Lisa Min-yi Chen Smith earned her Bachelor of Science degree in computer science from the University of Kentucky in May 1986. She graduated with her Master of Science degree in computer science from Oklahoma State University in December 1990. In May 2006, she received her Doctor of Philosophy degree in computer science from Texas A&M University in College Station.

Dr. Lisa M. Smith may be reached at the Department of Computer Science, Sam Houston State University, Huntsville, Texas 77341-2090.