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STEFAN JUNESTRAND Being private and public at home - An architectural perspective on video mediated communication in smart homes KTH 2004

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Doctoral Thesis
Stockholm, Sweden 2004

KTH School of Architecture

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ABSTRACT

Video mediated communication (VMC) is a two way real time audio and video communication between remote places. VMC has the potential to be applied favourably to many activities, services and functions in smart homes. The concept of smart homes refers to homes equipped with technological systems and appliances enabling centralised or remotely controllable integrated functionalities and services.

The main question for the current research work is formulated accordingly: How can spaces for video mediated communication be designed and integrated into smart homes? The governing idea is that there are two main perceptions of space in the design and integration of video mediated communication into smart homes. One concerns the conception of *private* and *public spaces*, the other relates to the idea of *physical* and *digital spaces*. The interrelationship between these two concepts is supposed to become important when VMC is considered for smart home applications.

This thesis is written from an architectural perspective. It refers to the functionalistic paradigm here defined basically as the set of essential functions of the home that have to be solved in order to achieve good dwellings. The function of the home can be described as the organisation of space and furniture to support activities and processes in and around it.

The thesis is based upon five papers and a covering text providing background, analysis and reflection, as well as ideas on further development. The research method can be described as mainly explorative and design-oriented.

A principal result from the study is that a novel modality of space, the public digital space, appears when VMC is introduced into smart homes. Further, it is advocated that this modality is a relevant issue for the architectural profession and architectural research.

Keywords: *architecture, broadband, design, design theory, digital, dwelling, flat, physical, private, public, function, home automation, intelligent buildings, media space, multimedia, residential gateways, security, smart homes, space, telecommunication, video mediated communication, VMC.*

PREFACE

My interest in smart homes began in 1993 when I did my diploma work at the School of Architecture at KTH (Royal Institute of Technology) in Stockholm, Sweden. The work concerned a proposal for an architectural competition of the national Swedish housing exhibition held in Umeå in 1994 with the theme “ideas for the future dwelling”. Our proposal, made in collaboration with my wife, architect Ines Leal, was named "Virtual Reality" and was based upon the spatial integration of dwelling and work. The proposal was selected and built as a full scale model for the exhibition. In connection with that project we started our own studio, Leal & Junestrand Architects. For several years we worked with projects related to new ways of working and living with new information and communication technologies.

In 1996 I met Professor Ulf Keijer at the School of Architecture at KTH. Ulf worked with several projects related to ICT (information and communication technologies) in dwellings. Later that year I started my doctoral studies in his department.

In 1997, I got in contact with the Centre for User Oriented IT Design (CID) at the Department for Numerical Analysis and Computer Science (NaDa) at KTH. I started to collaborate with a research group based there, called “Smart Things in Smart Environments”. The main project that I was involved in was “comHOME”, a full-scale model of a flat of the future.

In 1998 I presented, and was accepted, for a licentiate degree with the thesis ”IT and the dwelling – an architectural perspective” at the School of Architecture, KTH.

In 1999 our research group at CID was absorbed by the Interactive Institute and my part time employment from CID was transferred to there. The group also changed its name to “The SMART Studio” (Smart Things for Art and Daily Life). My principal work at the Smart Studio was the making of a movie called “Private and Public Spaces – the Use of Video Mediated Communication in a Future Home Environment”, recorded in the comHOME flat.

In 2000 we moved to Spain, being my wife's home country. In the same year we founded CASADOMO.com, now the world leading smart home portal in the Spanish language.

A great number of people have contributed to the progress and final outcome of this work. I would like to thank them all, however only a few can be mentioned.

In particular, I am deeply grateful to my principal supervisor Professor Ulf Keijer. Since the start of my research work in 1996, he has, in a constant and inspiring way, guided me into academic work and how to get out of it on the other side. Continuously Ulf has, in an open minded, critical, sharp and yet creative way, listened, analysed and given feedback and ideas on my research. He has inspired me to always do my very best and force myself a little extra. He has almost unconditionally supported my desire to try and explore new issues. Despite the large distance between Madrid and Stockholm separating us during the last four years I have been able to finish this work thanks to Ulf’s generous way of adapting methods, place and time for common work, to my very special needs.

I would like to thank all the other members of SIBElab, our research group at the School of Architecture, especially Stig Gustavsson, Magnus Hunhammar, Göran Molin and Greger Sandström. I also want to thank all other members of the School of Architecture, especially to Professor Bo Göran Hellers and former Professor Sture Samuelsson, at the department of Building Engineering.

Dr Konrad Tollmar whom I worked with during my time at CID and the Interactive Institute guided me in the world of human computer interaction. Professor Yngve Sundblad at CID and Ingvar Sjöberg, director of the SMART Studio at the Interactive Institute, were both supportive and interested in my work. Ingvar was especially instrumental in his support for the making of the comHOME movie. I owe a lot to everyone at CID and the Interactive Institute whom I met and collaborated with during my time there.

Thanks to Dr Tomas Wikström at Lunds Tekniska Högskola who has led several seminars concerning my work, resulting in valuable improvements and focus of my research.

Lasse Lindblad and Rolle Bohman, at former S-lab at Telia, financed and offered the place for the design and development of the comHOME flat, as well as collaboration in the planning and realisation of the flat and several of the studies.

Gillis Edholm and Jonas Erkenborn at Svenska Bostäder, Björn Nilsson at Ericsson and Monika Brydsten, Stefan Lundberg and other members of the "IT-BO Projektet" in Vällingby let me participate in their development work and share ideas, knowledge and experiences.

I am very grateful to all the people with cognitive disabilities from Kungsholmens Dagliga Verksamhet who participated in the tests in the comHOME flat, as well as all the members of staff, especially Carina Berglund and Marianne von Döbeln.

Thanks to Inger Krantz and Diana Walters for their help with the improvements of the English language.

The early periods of the research was granted financial support by the Swedish Council for Building Research (now Formas) and the Swedish Agency for Communication Research (now Vinnova), which is duly acknowledged.

Finally I would like to thank my family for all the support and interest they have put in my work, especially my wife Ines Leal and my children Laurentina and Axel for being there and supporting me, even when I was working during vacations, weekends and early mornings.

CONTENTS

1 INTRODUCTION

The governing question forming the rationale for this thesis is: How can spaces for video mediated communication be designed and integrated into smart homes? The subject does not only concern the shaping of spaces, it also relates these spaces to their use, the social and cultural context of the home as well as the functions and services of the smart home, and specifically video mediated communication (VMC).

Video mediated communication (VMC) is a two way real time integrated audio and video communication technology between remote locations.[1] The hypothesis is that VMC offers vast potential for a number of different applications in the domestic environment, of which figure 1 illustrates an example.

Figure 1. Image of the use of the videoTORSO, a video mediated communication set-up for informal everyday communication, in the comHOME apartment. (Source: Junestrand et al., 2000, Paper 3)

Smart homes refer to homes equipped with technological systems and appliances able to offer centralised and/or remotely controllable integrated functionalities and services. The technological infrastructure of the smart home contains *home automation* systems, *security* systems, *multimedia* systems, *telecommunication* systems and *residential gateways*. The aim is to generate and improve the users' appreciation and benefit with regard to security, comfort, health, flexibility, communications, entertainment, efficiency, etc.[2] Intangible qualities like well-being, prestige and self-esteem should not be disregarded; however, in this work, it is not in focus. Presently, smart home solutions, to a widely varying degree of sophistication, are increasingly being introduced and deployed. In parallel to the smaller system integrators and manufacturers, several leading real estate companies and service providers now offer smart home solutions both for new and existing dwellings.

1.1 From Telephone to VMC

In order to better understand the potential of the development of VMC in the domestic environment, a similarity can be drawn to the introduction of telephony. Telephony was introduced into the home

[1] Finn et al., 1997.
[2] See for example Nyman, 1998.

environment on a large scale at the beginning of the 20th century. It became possible, still being at home, to communicate with people far away. The separation in space that earlier isolated the home from the outside world was technically eliminated. This is to be regarded as a fundamental breakthrough in everyday life for the average person. At the very beginning though, telephony was criticised from a social or psychological point of view, as it did not allow the person with whom the conversation took place to be seen. Nevertheless its usefulness was apparent. After a short period of time most people accepted this new way of communication and could not spare it as a necessity.

However, the telephone service is confined. It was designed for real time speech communication between two individuals. It transmits very limited information about the home environment to the outside world and vice versa. Some sensations about what was going on at home could unintentionally be transferred, like a child's uneasiness in the background. Equally, a feeling of what was going on at the place where the other person was located could be transmitted back. The telephone, though, did not affect to any noticeable extent the architectural design of the home.

The traditional telephone is extremely narrowly banded and offers voice transmission only. The access network that carries the telephony signal has recently been upgraded to a higher transmission capacity. This new technology, permitting very high transmission speed over the telephone network, is called broadband.[3] Broadband communication supports transmission of dense streams of digital data, like video on demand, on-line gaming and other new applications and content that will emerge.[4] A vast number of new products, content and services taking advantage of broadband accessibility are being developed and provided for the home by both private and public service providers. Broadband development and implementation form an important part of the strategy for the political

[3] Other access communication network infrastructures used for Broadband access communication to the home are e.g. cable television network and electrical network, Fröroth, 1999, pp. 24-25.

[4] Broadband here refers to a permanent connection for voice and data communication with relatively high capacity of data transmission. About 2 MB/sec. is the lowest transmission capacity that technicians use to define Broadband. ADSL connections of no more than 256 KB/sec. are though included in the concept of Broadband when operators commercialise their products, and when many statistics, etc. are presented.

and economical development of society.[5] One application taking advantage of the uninterrupted Internet connectivity based on broad bandwidth, with a potential for wide and deep penetration into the domestic environment, is VMC.

1.2 A Changing Idea of the Home

The basic function of a home is its ability to offer shelter. Shelter from the environment, be it harsh weather – sun, cold and storm – threatening animals or hostile human beings. The home has also been the central place in man's life ever since the emergence of an agricultural society when man transformed from being a nomad to living in a defined place. With the change of technology, lifestyle, work and social life through history, the construction and physical form of the home has changed. So has its use, and along with these changes, its meaning for its inhabitants. From being a rather public place in the *agricultural society*, with a place for the family including servants and open air workers, the home in the *industrial society* became more private, basically arranged for a single family living on its own.[6] [7]

Now at the beginning of the 21st century, in the *information society*, the role of the home seems to be in a process of change once again.[8] The dwelling appears to play a more central role in many people's lives than it did in the later phases of industrial society.[9] [10] Society as a whole develops new social structures, cultural forms and new ways to work and live, which occur also in our homes. The time spent in the dwellings is increasing as well as the size of the housing units.[11] At the same time, the size of households is decreasing, making more space available for each person.[12] If this is in compliance with a long term sustainable society cannot be predicted at this point in time. The present socio-economic development in Sweden and elsewhere is very

[5] Metropolitan Area Networks & Broadband Services, 2003.
[6] Rybczynski, 1988.
[7] Junestrand & Tollmar, 1998 (Paper 1).
[8] Mitchell, 2000, pp. 72-73.
[9] Gustavsson & Keijer, 1999, pp. 24-25.
[10] Molin & Franzon, 1997.
[11] Castells, 2000, p. 400-401.
[12] ibid, p. 362.

much open for discussion and analysis, though it is not a subject for further consideration in this study.

New information and communication technologies (ICT) develop fast. There are reasons to believe that ICT will have a strong impact on home life and the way we use space at home.[13] The home is a place for integration of new ICT-equipment such as computers, home networks, alarms and game consoles, and more and more of these home appliances are being connected to home networks and the Internet.[14] Changing social behaviour and new technological applications, systems and infrastructure, require the idea of the home as such to be reviewed. Eventually, it may generate a need for a new design of the physical unit itself, which we call the dwelling.

The home, in general, is perceived as a *private* place. It seems though as if ICT, and especially VMC, is breaking up the traditional boundaries of the home, making the home more *public* than it used to be in the recent past.[15] [16] The home will have to adapt to a wide range of new activities, partly supported by VMC applications, such as tele-work, tele-education, medical consultancy and shopping using telecommunication and the Internet. These activities expand beyond the outer walls of the dwelling and engage the inhabitants in remote digital undertakings, from a physical place defined as "home". If this is true, how shall the profession dealing with the creation of homes relate to such thinking? It does not imply just a simple extension into the garden and the immediate environment. The new technology offers entirely new opportunities to extend our homes in space and time.

The smart home concept is rather new and unexplored within the architectural profession and the real estate market. However it is supposed to incur implications on the architectural design of the home. This results in a need for a new architectural design of the home as the home integrates new functions and services.[17]

[13] Hughes et al., 1998, p. 249.
[14] Mitchell, 2000, p. 72.
[15] Mitchell, 1996, pp. 99-100.
[16] Junestrand & Tollmar, 1998 (Paper 1).
[17] Mitchell, 2000, p. 73.

1.3 The Architectural Perspective

This thesis is written from an architectural perspective. A principal concept in architecture is *space*. Space is always inhabited when performing some kind of activity within the home. There are two governing perceptions, or maybe rather understandings, of space in the design and integration of video mediated communication into smart homes. One concerns the idea of *digital* and *physical spaces*, and the other relates to the conception of *private* and *public spaces*.

1.3.1 Digital and Physical Spaces

The *digital space* refers to spatial experiences that are generated by a technical system such as a television image, computer image, video-projection on the wall, etc.[18] Digital spaces can take two forms, abstract or representative. The focus in this study is on representative spaces. Representative digital spaces are digital representations of mainly three-dimensional real worlds or objects, i.e. persons, rooms, natural or artificial spaces. *Media space* is another concept used to describe a common digital space generated in VMC as a mixture of audio, video and computing.[19]

The *physical space* is the place where you are actually located with your body. Thus, a VMC system generates digital representative space of the remote communication space while the user is in a physical space.

Hence, the spatial experience for the user during VMC is generated by a mix of digital and physical spaces. The digitally generated space is global in the sense that the direct visual expression can be transmitted worldwide in real time while the physical space is local. These two definitions of space co-exist and both form important parts of the daily spatial experiences related to VMC in the smart home.

[18] Another concept is *electronic spaces*, which refers to television images etc. generated electronically and not digitally. Here this concept is included in digital spaces.
[19] Harrison et al., in Finn et al., 1997, pp. 282-283.

1.3.2 Private and Public Spaces

Figure 2. A typical toilet from a farm in Agricultural society. The toilet that in the Industrial society became a strictly private space, was, in the Agricultural Society, a public place used by many persons at the same time even in the domestic environment,. Image from Björnlunda Hembygsgård. (Photo: Ulf Keijer)

The concepts of *private* and *public*, respectively, were neither well defined nor strictly separated in agricultural society. People lived and worked inside the main building of the farm, outside close to the buildings, or in the fields. Privacy was not important, or perhaps just not possible. Often, many people slept in the same room and bed, and the common "toilet" consisted of many holes in a row, see figure 2.

In industrial society the separation of public spaces from private spaces became strict. In this era the home became the incarnation of the most private.[20] The private tended to be absolutely private and the public to be totally public. The earlier semi-public character of the traditional farmer's house disappeared in modern planning.[21] The boundaries between the public space and the private space came to be precise.[22]

The way we live in our homes in the information society is now becoming more complex. An increasing integration between work, purchase of goods and domestic activities is supposed to open up the strict separation between the private and the public. This is emphasised by the integration of VMC in the domestic environment, which opens up the dwelling to the outside world and brings the outside world into the dwelling, see figure 3.

The main architectural design issue for the integration of VMC into the smart home, however, is how the outside world, as perceived through VMC, is integrated into the design of the home and the problem of being *private* and *public* at home. Mitchell for example writes that videoconferences can link public to public, connect private to private, or electronically mix public and private.[23] Spaces within the home where you can be seen and heard during a VMC session become *public* in a new and specific sense, while spaces where you cannot be seen nor heard during or between VMC sessions remain *private*.[24] These *private* and *public digital spaces* could be regarded as a

[20] Norberg-Schultz, 1971.
[21] Junestrand & Tollmar, 1998 (Paper 1).
[22] Graham and Marvin, 1996.
[23] Mitchell, 2003, p. 29.
[24] Junestrand & Tollmar, 1999 (Paper 2).

novel architectural issue of form which makes it highly relevant to the scientific discipline of architecture. This is the standpoint of this work and it will be further explored.

1.4 The Setting, Structure and Writing

This work is a result of research and development activity performed mainly at the School of Architecture, KTH (Royal Institute of Technology), Stockholm, and in the research group "Smart Things and Environments for Art and Daily Life". The latter was initially affiliated to the Centre for User oriented IT-Design[25] (CID) at KTH, and later to the Interactive Institute[26]. Although performed in different settings with a number of projects of very different character, the work has been focused around the same research problem. Several fields of knowledge and scientific disciplines have influenced the work. As mentioned, the architectural field is central for the study, to a considerable extent other fields of technological and social sciences contribute, each one with their own framework of concepts and theories.

Figure 3. "mediaSPACE" a VMC set-up in the comHOME flat that let the people in the flat interact in remote events. (Source: Junestrand et al., 2000, Paper 3)

1.4.1 The Structure of the Essay

This first chapter of the study contains an introduction to the work, its purpose and concepts as well as the structure.

The second chapter contains a discussion of three significant research issues for the development and understanding of VMC related to smart homes. These are 1) current socio-cultural trends, 2) architecture and residential housing, and 3) technological development of the home.

The third chapter addresses the scientific framework for the study, its theory and methodology including the adopted limitations. It ends by establishing the research questions found to be of importance for the theme and suitable for the experimental and theoretical work.

[25] http://cid.nada.kth.se
[26] http://www.interactiveinstitute.se

The fourth chapter is a short summary of related academic research. It presents relevant Swedish and, to some extent international, architectural research. It is followed by an overview of research on smart homes and VMC from three domains: the socio-cultural, the technological and the architectural.

The fifth chapter summarises the five published papers which form an integral part of this work and their contribution to the theme of the research. It also gives an overview of the background and the design of comHOME, the test flat which formed the basis for most of the research undertakings for this present thesis.

The sixth chapter presents the results of the work primarily by answering the research questions put forward in chapter three.

The seventh chapter contains the conclusions of the work and outlines some areas for future research. A list of references is given in chapter eight.

Finally reprints of the five published papers upon which the thesis is based, are included.

1.4.2 The Writing

Words, and concepts, that are intended to give an emphasis in the given situation are written in italics, e. g. *smart home*. When referring to the author of a general work, it is written with a lower case "a" (author), and when referring to the author of this work it is written with an initial capital "A" (Author).

In the foot notes a reference might indicate the author and the year of the refereed work. Page numbers are indicated in most cases where it refers to a specific part of the work or to a quotation. When the page number is not indicated the reference is more general.

To conclude, the present chapter forms an introduction to the presented work. To proceed, the following chapter will be devoted to a more detailed exploration of the context of VMC and smart homes.

Further descriptions in this work primarily concern the Swedish situation, if not explicitly expressed otherwise.

2 SMART HOMES – ROOTS AND CONTEXT

An architectural perspective on VMC in smart homes is a complex issue conditioned by many factors. This chapter aims to define and introduce the roots and the context of the chosen theme by giving an overview of some areas of special interest for the work. Socio-cultural trends, architecture and residential housing, and the technological development of the home were identified as three productive perspectives to be analysed in this context.

2.1 Socio-Cultural Trends

Trends and tendencies in society are both a prerequisite and a condition for this work. Some socio-cultural trends found to be of special importance are discussed below.

2.1.1 The Information Society

The idea of the Information Society[27] is rooted in the United States (US) in the 1950s, when the important shift from mainly military use in the aftermath of the second World War to business and then to civil applications became manifest. In 1955, information workers displaced industrial workers in number in the US. Other nations like Canada, England, Sweden and France were not far behind.[28] Now, at the beginning of the 21st century, the whole western world, the OECD community, is a part of the world-wide information society, and important parts of Asia are close behind.[29] Information and communication technologies have been the prerequisite for this development. Still newer technologies are emerging as well as further changes of society as a consequence of this shift.[30] Castells asserts that social changes are as dramatic as the technological and economic processes of the ongoing transformation.[31]

[27] Other concepts used to describe this society are the Informational Society, the Network Society, the Post-Industrial society or the Service Society.
[28] Rogers, 1986, pp. 12-14.
[29] For an extensive discussion about the information society that deals with most of the aspects mentioned here, see Castells, 2000.
[30] Rogers, 1986, p. 12.
[31] Castells, 2000, p. 2.

2.1.2 Time

Time is a concept with many different interpretations.[32] Our relationship to time is complex. In the old agricultural society the relationship between man and time has been described as being circular. The very cyclical nature of time itself, repeating the day, the month and the year is based on the circular rotation of the earth itself and around the sun, and that of the moon around the earth.[33]

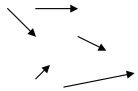
PERCEPTION OF TIME			
Socio- Economical Structure	Agricultural	Industrial	Information
Interpretation	Circular	Linear	Pluralistic
Graphic Illustration			
Driven by	Natural Rhythm	Human Planning	Subjective Events

Figure 4. Graphic illustration of the different perceptions of time through history. (Based upon Junestrand & Tollmar, 1998, Paper 1)

Industrial society's demand of a precise and chronological order in production and distribution changed the perception of time from circular to a linear interpretation. The circular order of time was replaced by the concept of time as something exact and objective. This conceptual change became scientifically confirmed by progress especially in physics in the first half of the 20th century (the "time arrow")[34]. In manufacturing, "Taylorism" became the keyword for this transformation during the same period of time.[35] The production of goods and services was measured in time units and similar studies on efficient use of time were performed, even of household activities.

[32] Davies, 1995.
[33] ibid, pp. 28-29.
[34] ibid, pp. 29-33.
[35] Taylor, 1913.

Time, in the information society, is perceived as polychronic, i.e. a "system of time that is simultaneous".[36] This means that due to developments in telecommunications and increased connectivity, much of our daily activities are trigged by events rather than by the clock, see figure 4. Modern digital systems not only mark time, they trigger the execution of instructions, programmes and events.[37] An online world is also an example of the concept of pluralistic time, where you can perform tasks and participate in multiple events simultaneously. For example, we might receive an unexpected email, SMS or a call on our mobile phone which leads us to take some immediate actions which define, affect or change the activities of the day. Figure 5 is an illustration of this kind of sensation. It may appear as if there is no longer a natural, human rhythm that determines the order at which events follow each other, but rather the accelerating pace of technology.[38] This event-trigged lifestyle obviously causes conflict in the domestic environment as well. Should, for example, a call on the mobile phone during the family dinner be answered or should it be redirected to the answering machine? Albeit most people agree that such a phone call should not be answered, the fact is, that people generally would answer the call.

Figure 5. A clock showing "NOW", a possible illustration of the event-triggered relation to time in the Information Society. (Source: Mead & Pacione, 1996, p. 74)

2.1.3 Connectivity and Networks

Connectivity is a phenomenon that is further developed by the infrastructural nature of technological networks and their applications.[39] Connectivity has become the defining characteristic of our twenty-first century urban condition.[40] People increasingly view the world as a place in which they are connected with each other in networks. One expects, to a large extent, to get a hold of another person, both concerning private and business issues, at almost any time of the day all week around. *Always-on* is a concept emphasising connectivity and describing a means of always being connected to the Internet, to be able to access information, and to be reachable through a variety of communication devices.

[36] Mead & Pacione, 1996, p. 75.
[37] Mitchell, 2003, p. 12.
[38] Visions of the Future, 1996.
[39] ibid.
[40] Mitchell, 2003, p. 11.

A concept related to connectivity is the network. The network refers to the development of the network society, with globalisation of business, culture and social structures of personal and organisational networks.[41] The information society is, at the same time as it is global, a very individualised society with rapid changes both in professional and social life, since the new information technologies make it so.[42]

2.1.4 Lifestyles and Equal Opportunities for All

Lifestyle is a sociological concept that has become instrumental for studies of social change in recent decades. Theoretically, people can be classified into groups defined by specific lifestyles, such as family structure, economic status, consumption habits, personal interests, health, etc.[43] The different lifestyles of members of the family and of society change and generate new forms of social relationships. This is both a consequence of new communication technologies and a reason for taking them into use.

The sketchy descriptions above of some concepts concerning notable societal trends could be considered as a relatively true characterisation of how large parts of the population live their contemporary lives. However, this is not the case for all citizens.[44] With the rapid transformation of society, new problems are prone to occur, leaving behind those people who are not able to keep up with the changes. Low education, location in small and remote places, different forms of disability or being old are obvious obstacles for many. Technological applications have been criticised many times for isolating people, but it should also be underlined that they can create the opportunity for many to live a more independent life than they would have been able to without the technology. For example, people with physical and cognitive disabilities have much to benefit from proper use of new and advanced technological applications.[45] A large portion of these

[41] Castells, 2000, pp. 77-147 & 357.
[42] Rogers, 1986, pp. 12-13.
[43] See for example Molin & Franzon, 1997.
[44] This has been described as the "80-20" society. It refers to a society affected by the rapid development of technology that continuously changes the labour market, social life and personal living at a very high pace. Large groups, about 20%, of the population will not able to keep up with the demands and the speed of the market, and will be left behind the remaining 80%. Rogers, 1986, pp. 165-166.
[45] Molin & Keijer, 2003.

groups should be able to obtain easier access to information, communicate and participate in different activities via the Internet, video-conference and e-mail from their homes.

2.2 Architecture and Residential Housing

This section gives a brief review of the building of residential housing in Sweden and related architectural and political issues from the beginning of the 20th century.

2.2.1 Functionalism

The dwelling conditions for the working class during the 19th century and the beginning of the 20th were very bad in Sweden.[46] Much of the population lived in poor conditions. Housing surveys showed that many homes were primitive. Rents were hardly affordable so that many families had to crowd together, even into one-room flats. Clearly, something had to be done.[47] A strong political movement demanded an improvement of the dwelling situation for the working classes. At the same time, but on the whole independently, the dwelling became considered an infrastructural resource, well illustrated by Le Corbusier's quote[48] "The house is a machine for living in".

The Stuttgart exhibition in 1927 was the principal break-through of modern functionalistic architecture. A large number of the leading European radical architects participated. The uniqueness of that exhibition and its importance is to be found in its "social" programme. Homes for all social classes were exhibited, not just exclusive houses for the upper class.[49] One year after the Stuttgart exhibition CIAM (Congrès International d'Architecture Moderne) launched another large exhibition in Paris with the theme "The Dwelling for the Minimum Subsistence Level"[50]. Here it was shown how cramped dwellings for poor European workers could be designed with a strict

[46] Housing and housing policy in Sweden, 2001, p. 3.
[47] Holm & Fredlund, in Fredlund, 1991, p. 43.
[48] Le Corbusier, 1986 (orig. from 1923), p. 14.
[49] Rådberg, 1972, p. 14.
[50] Original title in German "Die Wohnung für das Existenzminimum".

functional separation of minimal areas.[51] These two exhibitions formed a pioneering work by introducing a new attitude towards the home as an important task for architects and a significant architectural issue.

From the 1920s onwards *functionalism* started to play a role in the comprehension of the home and its functions. Interest emerged initially from a political point of view.[52] Soon sociological and architectural perspectives became material.[53] [54] Thus, from being a domain of limited architectural interest for hundreds of years, the dwelling turned into a major area of architectural practice and research, even amongst leading architects.

Figure 6. Floorplan from the Stockholm Exhibition 1930. By Erik Fiberger. (Source: Holmdal Andersson in Thiberg (Ed.), 1985, p. 79)

At the Stockholm Exhibition in 1930 it was shown how dwellings of different sizes and for different user groups could be designed with a strict functional separation of spaces for different activities[55], see figure 6. At this event a broad Swedish public met these revolutionary ideas for the first time. "Accept"[56], a written programme for modern Swedish architecture was presented the following year in 1931. It was propagandist writing for a new modern "functionalistic" architecture by some young architects, who quickly became some of the leading Swedish professionals during the 20th century.

From this period onwards, the ambition to improve dwelling conditions for people in general became more widespread. Since the functionalistic ideology was closely related to the powerful social reforms of the 1930s and 1940s, it had great influence on housing and physical planning in Sweden during the decades ahead.[57] Through studies of spatial requirements for furniture and for human beings, this and other works aimed to determine the minimal spaces of the different functions necessary for adequate living at home.[58] Politicians, construction companies and architects, all honoured the idea that good dwellings should be achieved by research, regulations, planning

[51] Holmdal Andersson in Thiberg (Ed.), 1985, p. 78.
[52] Björkman in Thiberg (Ed.), 1985, p. 80.
[53] Sandström, 1989, pp. 84-94.
[54] Housing and housing policy in Sweden, 2001, p. 3.
[55] Holmdal Andersson in Thiberg (Ed.), 1985, pp. 78-79.
[56] Asplund et al., 1931. Original title in Swedish "Acceptera".
[57] Holmdal Andersson in Thiberg (Ed.), 1985, p. 80.
[58] Sandström, 1989, p. 127.

and building programmes.[59] The combined work, aimed at guaranteeing the quality of the dwellings, continued and resulted in publications, guidelines, and building codes.

The contemporary proponents of the new information and ICT technology could be said to find themselves in a similar situation as these early pathfinders of functionalism for living spaces. Today, to apply ICT in homes is an area yet to be explored. Possibly some threads could be developed out of the experiences of Sweden during the few decades following functionalism and its break-through in architecture and housing.

2.2.2 Modernisation

The political agenda during this period of time was characterised above all by the key-word "Modernisation". The demands underpinned by unemployment and housing shortages after 1945 became directly related to national economic policy. Industrial rationalisation, mass production and standardisation supported the restructuring of production and building. There was a wide belief that, with the use of technology, a more just and equitable society could be established.[60]

Simultaneously, the development of building rules and legislation became more and more detailed.[61] In the 1940s and 50s this was accompanied by publications like "Good Dwellings, today and tomorrow"[62], a folder about building rules necessary to fulfil in order to be granted advantageous public loans for new housing, including a discussion about what constitutes good quality of dwellings and living spaces. "Good Dwellings, today and tomorrow" is still a useful example of what was achieved through planning during this period of time. Initially the laws and rules were aimed to guarantee minimum requirements, but soon they became normative.[63] A strong uniformity developed, which, in retrospect, has hidden some of the very positive

[59] ibid, chapter 4.
[60] Rudberg in Swedish Planning in times of transition, 1991, p. 108.
[61] For a comprehensive discussion about Swedish building rules during the last centuries, see Björkman in Thiberg (Ed.), 1985, pp. 84-94.
[62] Original title in Swedish: God Bostad, idag och imorgon, 1954.
[63] Sandström, 1989, p. 77.

outcomes from this systematic research on homes and their use during the middle of the 20th century.

This described development culminated in the 1960s and 1970s with a set of very comprehensive normative building legislations. Architectural design ambitions during this period were repressed in favour of the ambition to achieve an industrialised building process based on standardisation.[64] In 1965 the "One-million-programme" was launched, aimed at constructing one million new dwellings during a ten year period.[65] The final result of this comprehensive building programme has been much debated over the years. Many considered the outcome successful and by and large complying with the expectations once promised.[66] Others say that the long-term effects of the programme are more or less disastrous and now constitute severe problems related to lack of social cohesion and obvious tendencies to segregation in the housing of that time.

2.2.3 From the 1980s Onwards

In the two last decades of the 20th century the design of new dwellings was still strongly rooted in an industrialised tradition of architectural design. To some extent however, the design became inspired by international post-modernistic trends, for example, open floor-plans and a more generous attitude to building decorations. The building legislation loosened and new typologies for dwelling design were tried.

The trends are now pointing towards architectural design being more complex, diversified and intellectual than ever before. A more market-oriented attitude is apparent and some deregulation of the housing market has taken place. A long term client-provider relationship with improved customer care is in focus; coupled with continuous improvements of the housing company's internal processes, increased service quality to the tenants, increased quality of the employees at all levels, and the focus shifting from the building to the clients' living

[64] ibid, p. 325.
[65] Cars & Hårsman, in Swedish Planning in times of transition, 1991, pp. 56-57.
[66] Krantz in Thiberg (Ed.), 1985, pp. 103-104.

situation in the local context. ICT is becoming an important tool used to achieve these objectives.[67]

Regarding ICT, a strong political interest has recently emerged to improve the broadband infrastructure for dwellings and local communities.[68] Public administrations envisage being able to save money in health-care, to make it possible for an increasingly elderly population to remain longer in their own homes, to increase the opportunities for social integration and equality for disabled people and to uphold existing and create new and better services to groups even in sparsely populated areas. Not only are the homes as such of interest. The vicinity of the home, the local community, its services and its opportunities to offer physical meeting places interact with the home and its inhabitants. The development of smart homes should include due consideration to the community as an integral part of the home.[69]

2.3 The Technological Development of the Home

Human beings have always tried to adapt and to introduce technological advances and inventions into their living spaces, see for example figure 7. The motives have been very diverse, ranging from the development of new building techniques, to increasing health and safety, lowering costs, or to simply making the home more comfortable and pleasant.

2.3.1 Information and Communication Technologies at Home

The first general breakthrough of *information and communication technologies* (ICT) in the home was the telephone, as discussed earlier. During the twentieth century many other forms of ICT, often related to entertainment, were also introduced. In particular, the TV contributed to the creation of new socio-cultural patterns. It turned the under-used living room into a real living room and successively into an all-purpose room.[70]

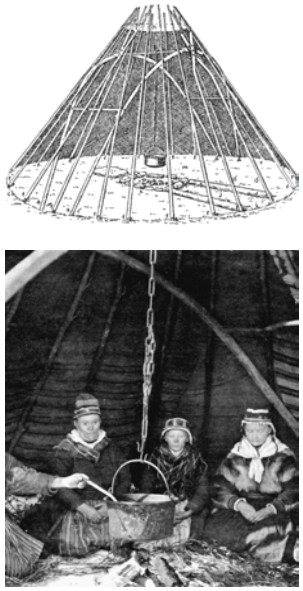


Figure 7. Top and Bottom Image: Cooking installation in a traditional cone-shaped Laplanders hut. (Source: Erixsson, 1947, pp. 50- 51)

[67] Junestrand & Keijer, 1998, p. 62.
[68] IT-infrastruktur för stad och land, 2000.
[69] Grahan & Marvin, 1996, p. 4.
[70] Krantz in Thiberg (Ed.), 1985, p. 99.

In the 1980s, game consoles were hooked into TV sets. Many recently established social rules for how to behave in front of the TV set were abolished. Also the first personal computers (PCs) in the home were introduced. The development took off in the 1990s when the PC became the tool for connection to the Internet. [71]

2.3.2 Video Mediated Communication - VMC

An application taking advantage of the uninterrupted Internet connectivity based on broadband, is *video mediated communication* (VMC). The necessary communication infrastructure, such as broadband connections, cameras, screens, microphones and loudspeakers are readily available. Video communication applications for PCs, and in some cases the television, as well as advanced video conference systems for professional office use are also available. Still missing though, are integrated VMC systems specifically developed for home use.

VMC can be seen not just as a substitution for co-presence, but also to provide new resources for communication and collaboration. Neither is VMC necessarily based around a "telephony" model of communication involving only explicit "call-style" connections. Instead, cameras, monitors and systems sensing electronic events are "left on" continuously, providing accessibility to public and private spaces.[72] VMC offers an alternative to being physically together[73], see figure 8.

Currently VMC has its predominant implementations in video conference systems for office applications. VMC is also well suited for informal communication[74] and here primarily supports the social and emotional aspects of communication in general.[75] [76] This fact makes it

[71] It is interesting to note that still no natural generic place has been found to put the PC in the home. It is placed in the bedroom, living room, kitchen, or hallway, often with poor ergonomics, lighting, acoustics, safety and functionality as a result.
[72] Bellottti & Dourish, in Finn et al., 1997, pp. 245-272.
[73] Harrison et al., in Finn et al., 1997, p. 293.
[74] Bly, 1993.
[75] Kraut & Fish, 1997, in Finn et al., 1997, pp. 541-559.
[76] Whittaker, 1995.

useful for the expected mixed demand required for domestic use.[77] VMC has the potential to be applied favourably to different activities, services and functions in the home. Groups with special needs, such as children, elderly people staying longer in their own homes and people with different kinds of disabilities may become particularly advantageous users of this technology in the short run. Students and professionals working from their homes are potentially early adopters of this technology. In a slightly longer perspective a wider consumer market for different VMC applications such as work, studies, care of elderly and disabled people, leisure activities and consultations with a bank or a doctor, is anticipated.[78]

Figure 8. A family meal situation using VMC to eat dinner with a person "remotely present". (Source Junestrand et al., 2000, Paper 3)

Homes in general are currently very badly suited for VMC. The homes' poor acoustics and lighting conditions, floor plans and spatial designs are obstacles, as well as the lack of technical infrastructure.[79] So in order to achieve successful integration of VMC in the domestic

[77] VMC also supports informal network building and maintenance, which might become even more important for the individual as an increasing amount of professional work is carried out at home.
[78] Junestrand & Tollmar, 1998, pp. 243-246 (Paper 1).
[79] Junestrand & Tollmar, 1999, p. 129 (Paper 2).

environment it is necessary to reconsider basic technical and architectural design criteria of the home.

2.3.3 System Integration

The integration of different electronic and technical systems, networks and their functionalities in a building is called *system integration*. It has its technological and functional root in *intelligent buildings*[80] that arose and became an important concept in the 1970s.[81] Intelligent buildings focused on commercial premises providing controlling and automation primarily from a building management perspective.[82]

For ordinary homes there exists a large number of practically autonomous systems and networks not connected to each other, like telephony, access control, the TV, PC (data) networks, appliances, HVAC (heating, ventilation and air-conditioning), and security systems. Attempts to integrate these separate household systems into networks and more complex systems have been around for many years, but are currently coming to maturity. This leads to the concept of smart homes, developed in the next section.

2.3.4 The Smart Home Concept

Smart homes are homes with integrated technological systems and appliances able to offer remotely and/or centralised controlled functionalities and services (see also figure 9). The technological infrastructure is based upon:

- *Home automation systems* including the control (on/off, open/close and regulation) of systems and functions for lighting, climate control, blinds, doors, windows, locks, watering, white goods and the supply of water, gas and electricity, etc.
- *Security systems* referring to alarms for intrusion (movement detectors, door and window detectors, glass break detectors), personal alarms (key fobs, wireless wristband transmitters and

[80] Smart buildings, high-tech buildings, integrated buildings and advanced technology buildings are other concepts which all could be subsumed into the concept of intelligent buildings, Kroner in Lustig (Ed.), 1995, p. 65.
[81] Abramson in Lustig (Ed.), 1995, p. 309.
[82] Lustig (Ed.), 1995, p. 320.

pendant transmitters), technical alarms (fire, smoke, gas, water leakage, and failure of electrical supply and telephone line) and remote video control for the protection of property, possessions and persons.

- *Multimedia systems* including the capture, treatment and distribution of audio and video within, from and to the home, such as audio/video multi-room, home cinema and PC media servers.
- *Telecommunication systems* encompassing the distribution and sharing of files and data amongst machines and humans through cabled and wireless local area networks, IP telephony, telephony, broadband access, routers, etc.
- *Residential gateways* have two main functions, one is to be a bridge between the home networks and the access networks as well as to be the physical interface between them. The other is to be an enabling platform for new digital residential services.

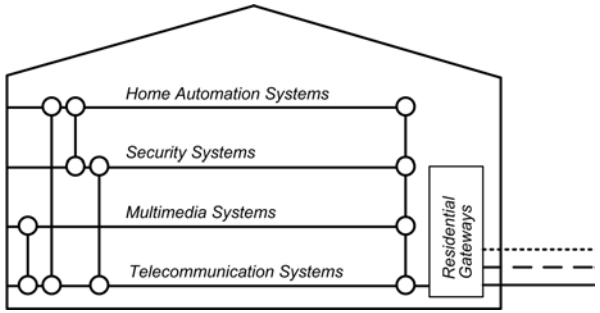


Figure 9. A schematic overview of the smart home technical system infrastructure. The access networks connect the building systems with the outer world.

2.3.5 The Smart Home Market

Until recently integrated smart home solutions were in general expensive high-end products and services. During the last few years less expensive systems have been developed. In combination with

cheaper and faster Internet connectivity to the home, new functional and useful solutions for the mass market have become available.[83] The smart home in this context becomes an attractive market for manufacturers[84] and service providers[85] entering the market for connected smart homes.[86] Simultaneously households now seem to find an actual value and interest in smart home applications.[87] [88] However different types of households and user groups have individual special needs and backgrounds and the marketing has to be custom-oriented to each group in order to become successful.[89] [90]

From an architectural perspective, the roles with special interest in the development of smart homes can be identified as the following:

- *Manufacturers and designers* – design and produce the hardware, software, applications and systems.
- *Architects and engineers* – design the home and specify its technological infrastructure.
- *Housing companies and developers* – procure, produce, sell, let and manage homes and residential premises.
- *System integrators* – integrate systems from different manufacturers into working services.
- *Installers* – install and maintain systems and physical installations.

[83] For example MyCasaNetwork (www.mycasanetwork.com) or Xanboo (www.xanboo.com) provide cheap hard and software platforms, for service providers, for home automation, security and remote video control and have broadband connections.
[84] For example BSCH (http://www.bsch.com), Fagor (http://www.fagor.es), Samsung (http://www.samsung.com), LG (http://www.lge.com) and Philips (http://www.philips.com).
[85] For example British Telecom (http://www.bt.com), Telefónica (http://www.telefonica.es), Securitas Direct (http://www.securitasdirect.com), Shell (shellhomegenie.com) and Enel (http://www.enel.it) are examples of leading international service providers that offer smart home solutions to end users.
[86] Nyman, 1998.
[87] Fröroth, 1999, p. 17.
[88] Sandström, 2003.
[89] Four household types with especially high consumption potential within the smart home market have been identified. The first is households with a working couple without children. The second is households with a working couple and older children. The third is single households with high mobility. The fourth is older people with decreased physical capabilities. Nyman, 1998, p. 35.
[90] Gustavsson & Keijer, 1999.

- *Service providers* – package attractive content and applications and offer it to the end users.
- *Content providers* – offer content and applications to the consumer directly or indirectly through the service provider.
- *The users* – use systems and consume services, can be both professional users and end users in their homes.

2.3.6 The Real Estate Companies

During the late 1990s a large number of purely experimental buildings of smart homes in Sweden and in other places around the world were constructed.[91] Later several real estate companies in Sweden – both large and small actors – have actually started to commercially develop full scale smart home projects. Below three projects of special interest are briefly described.

Vallgossen

Vallgossen in Stockholm is a residential unit with 126 flats completed in 2001.[92] The idea was to combine architecture and environment with modern technology to achieve improved security, safety, comfort and quality of life for the inhabitants. A goal was also to permit the users to continue to remain in their own dwellings even as they got older or if someone in the family became ill or disabled and needed more care. Three levels of IT services were made available. Level one included a data network, laptop, broadband and combined outlets for data and telephony and electronic keys. At level two the functionality of door phone with video display, delivery boxes and multi room audio network was added. Level three was developed as an R&D project in collaboration with a big hospital with a high level of home automation and control of lighting, outlets, blinds, water supply, door lock, and safety alarm[93], see also figure 10.

[91] In Sweden e.g. the comHOME project by Telia (Junestrand & Tollmar, 1999, Paper 2), IT-BO by Svenska Bostäder (Hunhammar, 1998), SmartBo by the Swedish Handicap Institute (Elger, 2002) and in Denmark VillaVision by the Technological Institute (Moltke et al., 1997).
[92] Sandström et al., 2003.
[93] Description based upon Sandström, 2003, pp. 29-33.

Figure 10. An illustration of how telemedicine makes it possible to visit the doctor virtually without leaving the flat or as in this case, even remain in bed, in one of the most IT-equipped flats of the Vallgossen project. (Source: http://www.jm.se)

Skogsbo

Skogsbo is a residential area of terraced houses outside Gothenburg, Sweden completed in 2001. The sizes of the houses vary from 100 to 135 m^2 and the prices range from €180.000 to €200.000 approximately. A basic service package contains individual metering of tap water and heating, a web camera on the car park, a weather station, broadband, Intranet, etc. The package is included in the price of the house. There are also a number of optional ICT services costing some €5.500. The additional services comprise a burglar alarm with an IR-sensor and magnetic sensors in doors and windows, a flood alarm that automatically turns off the water, a fire alarm and an embedded PC and workplace in the hallway, see figure 11. The additional smart home services enable the residents to control their homes via the computer, the Internet or by mobile phone. About one third of the residents have chosen the additional smart home services.[94]

[94] Nord, 2001, p. 22.

Tango

The most technically advanced house built at the national housing exhibition in Malmö in 2001 was the Tango house.[95] Each flat has a web pad – in essence a small portable computer – with wireless Internet access by which the smart functions in the home are controlled. A residential gateway manages the smart home functions and is the bridge for the functions and services between the home and the Internet. All lighting nodes have lighting services which permit individual control and predetermined lighting scenarios. There is a climate control in each room of the flat and a metering system for tap water and heating. An alarm system is integrated containing climate alarm (humidity and temperature), burglar alarm, fire alarm and sabotage alarm (the electronic hardware is protected). The alarm is relayed as SMS, over E-mail or fax, voice message on the mobile phone or through a lamp that turns on at home. All alternatives can be accepted or left out. The alarm system can be activated (but not deactivated) via the Internet, and a log system gives statistics about climate, temperature, door passages and alarms. Family services like an electronic notice board, chat sites, photo albums an electronic calendar are provided for each household member. The house and the individual flats have digital door locks where users can be added to the system and given limited access, meaning that friends, guests and craftsmen can get an extra key that only works within a limited time frame. Common services consist of entrance cameras and access to a local weather station. All these services, except the distribution of keys, can be controlled from the outside via the Internet. [96]

Figure 11. A touch-screen in the hall that permits control of the majority of the functions in the home, from a house in the Skogsbo project. (Source: http://www.jm.se)

In this section some Swedish examples were described pertaining to the ongoing development of the technological infrastructure of the home, and related services. The information and communication technologies (ICT) in general and VMC as well, will form important parts of our future homes. Sooner or later, most technological inventions end up as "standard equipment", like the cabled infrastructures for electricity, the telephone and the television in the past.

[95] A co-operation between the municipal real estate company Malmös Kommunala Bostadsbolag (http://www.mkbfastighet.se) and the smart home companies Frontyard (http://www.frontyard.se) and TAC (http://www.tac-global.com).
[96] Section based upon Nord, 2001, pp. 22-25.

Seen from an architectural point of view the design of the home will probably not adapt to the new technology until it actually makes a massive breakthrough into the home. This happened with the TV. Initially it was a "piece of furniture" which became integrated into the existing domestic environment. Later, when the social habit of watching the television was firmly established, the design of the home changed. It is more than likely that the emergence of the smart home will follow a similar pattern.

Socio-cultural and technical changes influence the development of homes over time. These changes interact and bear upon public policy-making in general, if they are strong and prevailing. In its turn, this may further reinforce the effects on housing development and housing design. The overview given in this chapter is an attempt to give a brief insight in these matters. The aim is to offer some foothold for judging what will be the appropriate position for the architectural profession in relationship to the mainly technical opportunities that probably will change the way we live our lives at home.

The next chapter is devoted to the scientific treatment of issues raised here and their relationship to the actual investigations presented in the papers.

3 THE SCIENTIFIC APPROACH

This chapter contains an introduction about *Architecture and Architectural Research*, followed by *Theories Relevant for the Study*, *Methodology*, *Delimitations* and *Research Questions*.

3.1 Architecture and Architectural Research

Architecture is an old craft – or profession – with a reflective, even theoretical, superstructure developed over centuries. As an academic discipline and research domain, architecture is young and in this respect driven by the challenge to develop and strengthen its own distinctive character. Gromark states that "Research can become a vital driving force behind the development of the identity of the architectural profession".[97] In his search for the nature of architectural research, Linn defined one possible starting point by emphasising knowledge as the preferred entity[98] "In architectural knowledge the understanding of a many-faceted reality is combined with a practically and empirically founded ability to handle complex systems altogether in a viable method, still hardly formulated theoretically, however, in reality rather advanced." Knowledge is also a key word with Mo[99] "There is a massive manifold within architectural research as the architects require knowledge in many fields". Linn further states that rationalising the study of architecture often induces an effect of reduction and, as a consequence, such studies lose their necessary holistic character. Architecture has to be comprehended on its own merits.

Architectural research is not a self-contained domain. According to Gromark it should be complemented by knowledge, methods and theories brought in from other research disciplines. "The architectural research aims at acquiring knowledge contributing to qualitative

[97] Gromark, 2000, p. 101. Original text in Swedish "Forskning och forskarutbildning kan bli en vital drivkraft bakom arkitekturyrkets identitetsutveckling.".
[98] Linn et al., 1998. Original text in Swedish "I arkitekturkunskapen har en mångfasetterad verklighetsförståelse förenats med en praktisk-empiriskt grundad förmåga till hantering av komplexa system, allt i en fungerande metod som teoretiskt ännu är föga formulerad men reellt ganska avancerad.".
[99] Mo, 2003, p. v. Original text in Norwegian "Det er stort mangfold innefor arketkturforskning fordi arkitekter har behov for kunnskap i mange felt.".

changes through the realisation of the architectural work, but also to a widened social participation and an understanding of architecture as a cultural expression. Research in and on architecture is identified by a multi-disciplinary approach where humanistic, social, technical and artistic points of view interact with each other".[100]

When these concepts are introduced into physical structures as buildings and spaces their feedback ultimately contributes to knowledge in the architectural domain. "Pure gathering of knowledge is not enough. The knowledge also has to be realised, interpreted, critically examined and implemented into the buildings. Not until then the research process delivers a real contribution to the social and cultural development through the researcher's participation. When achieved it appears in the encounter between research and practical reality, and material steps for genuine change can be realized."[101]

Before we proceed further it is necessary to touch upon another important aspect of architectural research. Many topics addressed by research in this particular discipline are related to other research fields, which implies the necessity to comply with their methodologies and research approaches. As Mo writes[102] "Recognition in the international and cross-over research disciplines requires that the researchers place themselves on the scenes for discussions on research philosophies. Standards and research requirements must not deviate too much from what has been researched in all other fields". One could add that architectural research on new artifacts to be introduced in our homes, based on information and communication technologies,

[100] Gromark, 2000, p 102, (Original text in Swedish "Arkitekturvetenskapen syftar ytterst till kunskap som bidrar till kvalitativa förändring genom arkitekturverkets förverkligande men också till en breddad samhällelig delaktighet och insikt i arkitektur som kulturuttryck.Forskning om och i arkitektur präglas av ett mångvetenskapligt synsätt där humanistiska, sociala, tekniska och konstnärliga infallsvinklar ofta bryts mot varandra.").
[101] ibid, p. 107 (Original text in Swedish "Ren kunskapsinhämtning är inte nog. Kunskapen skall också omsättas, tolkas, kritiskt granskas och implementeras i byggnadsverket. Först då lämnar forskningsprocessen, genom forskarens deltagande, ett verkligt bidrag till samhälls- och kulturutveckling, dess fullbordande sker i mötet med den praktiska verkligheten då viktiga steg till genuin förändring kan uppnås.").
[102] Mo, 2003, p. 10 (Original text in Norwegian "Anerkjennelse i det internatiosjonale og tverrfaglige forskersammfundet krever at forskere plasserer seg i landskapet av viteskapsfilosofiske diskusjoner. Standarder eller krav til forskning må icke avvike altfor mye fra det som forskning har vaert i alle andre fag.").

should have a reasonable prospect of being acknowledged by the applied research within the computer science disciplines, in as much as part of the research in these fields relates to the built environment.

Although the view of Gromark given above has not been adopted as "the" research method for the present study, it may still represent a perspective that has become attractive and helpful during the course of the work. The use of a full-scale building model[103] and the evaluation of designs by pursuing established methods[104] are important elements of the research process. This will be further expanded upon in the following section.

By making a synthesis of the points of view represented by the discussion above, and by adopting the essence of Gromark's ideas, a method for the research task was formulated and consists of a number of discernible steps, as follows:

- to define a specific architectural problem domain or problem within the smart home concept,
- to create a physical representation of (a part of) a smart home,
- to generate hypothetical scenarios for possible use of the new video mediated communication artifacts at home,
- to realise the scenarios in the created smart home with the purpose of demonstrating possible use of different technologies,
- to study people's behaviour when using these technologies,
- to take part in other investigations and thus to integrate acquired knowledge into current research,
- finally, to put forward clearly any findings from the investigation and to draw appropriate conclusions from the study as a whole.

The creative design-oriented approach is obvious. By applying such a procedure it can clearly be seen how the empirics will become an integrated part of the research. These areas will be discussed further below, each one in its specific context.

[103] A full scale smart home flat called comHOME designed by the Author. See section 5.1 and Junestrand & Tollmar, 1999, pp. 181-188 of the paper (Paper 2) for a comprehensive description of the comHOME flat.
[104] See for example Junestrand et al., 2003 (Paper 4) and Junestrand et al., 2001 (Paper 5).

This problem solving research position is commented upon by Mo[105], who denotes it as "modus 2 thinking". Modus 1 refers to scientific research within the traditional disciplines. Modus 2 thinking relates to applied research and is characterised by accumulation of knowledge through problem solving. Without exaggeration one can assert that with the emerging global technological networks and with the never-ending fierce international competition it is highly probable that an increasing amount of modus 2 knowledge will be developed out of university based research, in addition to the traditional research.

In the following section the theoretical framework for the study will be further elaborated. Of special interest are some novel ideas that seem to fit in with the present research and with its requirements.

3.2 Theories Relevant for the Study

This research work is multi-disciplinary in its approach and its realisation. It is complex as it touches upon a considerable number of research areas. It concerns design issues and is future oriented.

3.2.1 Design Theory

Human designed and constructed phenomena, including architecture, are artifacts. The science focused on the design of artifacts is called Design Theory or Science of the Artificial. According to Herbert Simon, the Nobel Prize laureate, the design process, contrary to the processes in the natural sciences, aims at defining how things *ought to be*, rather than how things *are*. Simon puts up four boundaries for the science of the artificial:[106]

" 1) Artificial things are synthesized (though usually not with full forethought) by human beings.
2) Artificial things may imitate appearances in natural things while lacking, in one or many respects, the reality of latter.
3) Artificial things can be characterized in terms of functions, goals, adaptation.

[105] Mo, 2003, p. 36 by referring to Gibbons et al., 1997.
[106] Simon, 1981, p. 5.

4) Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives."

This puts up the conceptual limits for a designed artifact. Simon does not go further in defining the process of the making of artifacts. Dahlbom, on the other hand, takes a bold step further by developing and criticising Simon - not for the approach as such – but for not bravely fulfilling his intended ideas. He also criticises Simon because he turned his design-oriented science of the artificial into a general theory of problem solving, adhering to the values of traditional empirical science, rather than following up on his very radical introduction.[107]

Dahlbom stresses the fact that we live in a world of artifacts which enable and influence our lives. When we realise that the world we live in is an artificial world, a world of human creation, made up of artifacts of all kinds, becoming ever more complex and intertwined, our attention will shift from studying nature to contributing to the design of artifacts. In the natural sciences one wants to find out what the world is like, while in the science of the artificial, one is interested in what could possibly be and how to make it so.[108] Such wording encourages the idea to investigate what could be desirable and possible in some specific architectural design situations and subsequently structuring, analysing, evaluating and communicating the findings.

3.2.2 Architectural Theory

The architectural theory referred to can be defined as a functionalistic theory. The functionalistic idea, in the architectural context, is that the functions of the home have to be solved in order to achieve good dwellings. The functions of the home can be described as the organisation of space and furniture in the best possible way, in order to support activities and processes within and around the building. In this study processes taking place within a dwelling are in focus.

[107] Dahlbom, pp. 13-21, in Dahlbom et al., 2002.
[108] Dahlbom in Dahlbom et al., 2002.

It is obvious, though, that architectural design cannot be defined only by meeting functional needs. It also carries meaning, history and other references, as well as being limited by natural laws, regulations, constructions and economy. Hence, the solutions of the functional aspects in architectural design are never pure, neither in theory nor in practice, they have to be understood in their context. "To create a totality with desired properties the architect requires knowledge about buildings as well as about social systems and their relationships".[109]

What is not referred to are the aesthetics and the political programmes[110] [111] to which the late functionalistic movement in Sweden was associated.[112] Nor is there a clandestine defence of the specific ideas, hidden in the agenda, about a strict static spatial separation of the functions in the home in different spaces, which was developed as general solutions by practitioners and researchers from the 1930s and beyond. Rådberg writes[113] "The differentiated floor-plan was developed, where different functions were separated and given their own space, within the spatial limits of the cube, at least to satisfy the most important needs of the dweller". Mitchell[114] underlines that "Time division and multiplexing of activities is starting to look smarter that space division". The functionalistic aspect of this study refers principally to how the design supports the real activities taking place in the home, how the needs vary in time and space, and how this knowledge could be applied in architectural design. However, as Dahlbom clearly states "A functional analysis will not tell us if the artifact is beautiful, what it means to us, how it will change our habits, or influence the struggle for power."[115] Despite this, the concept of functionality, as it is used here, represents a fruitful approach to the problems presented in this study.

[109] Ekholm, 1987, p. 15. Original text in Swedish "För att kunna åstadkomma en helhet med de önskade egenskaperna måste arkitekten ha kunskaper både om byggnadsverk och sociala sytem samt om relationerna mellan dessa.".
[110] Sandström, 1989, p. 266.
[111] Rådberg, 1972, chap. 4.
[112] Sandström, 1989, p. 50.
[113] Rådberg, 1972, pp. 114-115. Original text in Swedish "För att inom den hårt kringskurna rumskuben tillgodose åtminstone de viktigaste behoven inför man den diferentierade bostadsplanen, där olika funktioner i görligaste mån separerats och tilldelas specialutrymme.".
[114] Mitchell, 2003, p. 162.
[115] Dahlbom, p. 24, in Dahlbom et al., 2002.

Of course, to return to the old functionalism may seem challenging today as for many it appears more and more inconceivable, not least considering the effects of information technology. A common opinion about architecture, is that architecture limits itself to the physical space. This view is well expressed by Gabrielsson Åman, who refers to an indivisible whole in architecture hardly attainable even with a focussed intra-disciplinary approach. "Architecture is a manifestation of a tangible and physical reality, an authentic experience of here-and-now and the direct and unexpected moment that makes all translations superfluous. It is no more a question of beauty, of making things wanted. It is about presence and - if at all possible - to make our existential presence understandable."[116] The overall intention about architecture helping us to interpret the world around us is positive. However, as argued in this work, limiting architecture to the direct and contiguous physical environment is doubtful. Or as Mitchell[117] expresses it "The boundaries define a space of containers and places (the traditional domain of architecture), while the networks establish a space of links and flows."

3.3 Methodology

How can these theoretical ideas be applied in practical research work? Also, how can a problem be approached when defined in the middle of a dynamic developing process? These are two principal research challenges for the present study.

A first attempt could be to try to apply methods generally found in the disciplines of the behavioural sciences. Their main approach is that of observation. To observe strictly what is happening in the video mediated communication domain and to carefully follow and describe what is going on in different practical projects would be the research method of a behavioural scientist.

[116] Gabrielsson Åman, 1997, p. 130 in *Handla!*, 1997. Original text in Swedish "Arkitektur är manifestationen av en konkret och fysisk verklighet, en autentiskt upplevelse av ett här-och-nu och det direkta och oförmedlade ögonblick som gör alla översättningar överflödiga. Det handlar inte längre om skönhet, att göra saker och ting begärliga. Det handlar om närvaro – att överhuvudtaget göra vår existentiella närvaro begriplig.".
[117] Mitchell, 2003, p. 7.

However, the general methodological approach used in this study is different. It is proactive and participatory. Reflection, analysis and development are based on the experiences emerging from the work with different projects, paper-writing, and the continued testing and validation of these ideas with users and research colleagues. Thus, the working method can be described as mainly explorative. This approach does not exclude the application of formal research methods that are taken from natural or behavioural sciences, where appropriate.

3.3.1 Archaeology of the Future

According to Dahlbom, research on artifacts should be oriented towards the future. A research metaphor for this explorative science of the artificial is the *Archaeology of the Future*. While the archaeologist creates a picture of the past by searching for fragments from earlier cultures and synthesising and interpolating these fragments, the scientist of the artificial makes designs (fragments of the future) to model and simulate in order to imagine a larger or more detailed part of the future. [118]

Concerning the role of the researcher in this situation Dahlbom writes[119] "It means that rather than stressing such natural science values as careful documentation and reasoning, methodological acumen, knowledge of the field, the quest for abstract, fundamental principles, universal truths, the scientific community will begin to stress problem relevance, human interest, imaginative scenario building, and good ideas. It means that the academic researchers will gradually turn away from the never ending task of reporting, in greater and greater detail, what goes on in the world, and, in particular, what goes on in the world of scientific publication. It means that there will be a growing framework of future archaeological explorations of the socio-technical possibility space, providing a context for physical and social engineering design efforts, and a source of knowledge for decision makers of all sorts."

The science of the artificial is, in this aspect, opposed to the traditional objective social and behavioural sciences. The latter are in general

[118] Dahlbom, pp. 33-40, in Dahlbom et al., 2002.
[119] ibid, pp. 39-40.

based upon observations and a non-participating and non-interfering approach. This is apparently not valid for the science of the artificial. One problem, among others, for the traditional social and behavioural sciences[120], is to create sufficiently "clean" situations for observation and analysis. New concepts and methods need to be established, tested and accepted by the academic world. However, the fast development of society and of information technology makes such pure situations difficult to find.

Therefore, in the archaeology of the future, scientific approaches to design demands that the work in its elements uses methods from the natural sciences as well as from social and behavioural sciences. Further, the work should, where appropriate, be related and compared to approaches from other research areas working with a future oriented design approach. New methods assessing the results could be developed. As the work reported upon consists of a number of different projects and activities, several methods have been applied in the projects described, namely design work, interviews and observations and literature studies. Below some of these applied methods are described and discussed.

3.3.2 Literature Studies

An important part of the acquiring of information about research methods, theories, related work, etc, is achieved through literature studies. Traditional publications such as books and magazines, have been the key sources for information. The Internet has also been used as a source of information.

3.3.3 Design in Context

The comHOME project is the particular design project that has been most used for the tests and evaluation reported in this study. The design and establishment of the full-scale model flat went on for almost a year and was finished in autumn 1999. The Author was responsible for the design of the comHOME flat, from developing the first concepts until its completion as a test site. This activity was valuable for the understanding of the complexity of the development

[120] This refers to the traditional way to work within these research disciplines. A development of new methods is naturally going on there also.

of a smart home with a high level of integration of advanced systems, as well as for the proper understanding of the results from different investigations carried out on the test site with the installed equipment. Once the flat was built, the initial specific research activity was the recording of a short video in order to demonstrate and to test some of the design concepts. User studies with intellectually disabled people were carried out to evaluate certain design aspects of the comHOME flat.[121] Here a mix of observations and semi-structured interviews were used.

The specific research projects span the general to the particular. Within the different projects it has been possible to test and evaluate ideas concurrent to their design and realisation. The processes and experiences of these different projects were documented and fed back into ongoing and future work.

Figure 12. Image of part of the comTABLE pattern from the Private and Public Digital Domestic Spaces paper.

The paper Private and Public Digital Domestic Spaces[122] is primarily a test of Pattern Language (PL) developed by Alexander[123]. It is performed as a test of a method of design and communication, rather than of the specific set-ups, see figure 12. PL was not applied in the design of the set-ups, rather it was tried in order to explore if it was a convenient method for the design of general set-ups that comprise the video mediating artifact.

3.3.4 Papers and Presentations

The process of writing the papers became an important part of the research activity and an academic achievement. Simultaneously it became a part in the act of developing the designs. The process of writing contributes to the structuring and analysis of one's own work and brings results back into the current project or adds leading knowledge to subsequent undertakings. All papers of this thesis have several authors, which brought discussion and analysis into the specific process of writing. This process supported interaction between the authors and induced repeated reflection. The papers were also read, evaluated and criticised once they were submitted for

[121] Junestrand et al., 2003 (Paper 4).
[122] Junestrand et al., 2000 (Paper 5).
[123] Alexander, et al., 1977.

publication, and as a consequence were in general improved and then resubmitted.

3.4 Delimitations

An architectural perspective on VMC in smart homes covers a manifold of aspects. The main approach and aim is to study and structure the research subject, if possible to make a contribution to the architectural profession with new design ideas, and to contribute to the definitions of some core concepts. A work of this kind implies delimitations, which have to be made as explicit as possible.

The aim of this study was not to present or pretend to offer a generic model or an all encompassing solution to the design of VMC in smart homes. What is presented and discussed is rather a set of concepts concerning the specific problem of being private and public in relation to VMC in smart homes.

The perspective of this thesis is architectural. The theory is focused upon functionality and spatial design. Building technology and the construction process are not considered, although they both could and should be essential fields of study for the practising architect. Hence, the dwelling is primarily dealt with as a place for accomplishment of a number of activities.[124] [125] "Some activities within the dwelling can be performed without any specific spatial design or equipment. Other activities depend upon the spatial design. The bed, the closet, and the chair all need floor space and free space around them to be used."[126] The discussion of the dwelling is not limited to a specific architectural typology or floor-plan. Most interest has been devoted to flats in residential blocks, where limited space for obvious reasons causes most problems and conflicts when new technological applications are introduced and related activities compete for common spaces, either

[124] Junestrand & Keijer, 2001.
[125] Rydenstam, 1992.
[126] Hallberg & Thiberg in Thiberg (Ed.), 1985, p. 163. Original text in Swedish "Vissa aktiviteter i boendet kan utföras utan någon särskild rumsutformining eller utrustining. Andra är beroende av hur den fysiska miljön är utformad. Sängen, skåpet och stolen behöver golvyta och friyta för att kunna brukas.".

physical or sound.[127] Most literature related to homes addresses dwellings in residential blocks.

In Sweden, like many other countries, the largest part of the building stock needed for the foreseeable future already exists. The majority of the population does not have the slightest aspiration to acquire a new home just because it is smart. Yet the intention has been to push the discussion towards the limits of VMC, design, technology and applications. Thus, by this approach, as new criteria emerges and is considered, some features of a future smart home will assert themselves more clearly. So, these sharp-cut features can become objects for discussion in some specific user groups and become examined more thoroughly in other settings.

A related theory is Reflection in Action[128]. However, in the design process there is a clear difference between the practitioner and the academic researcher. In a way the practitioner contemplates deeply on motives and ends of his design as much as any researcher may do in his work. However, design should not be placed on a par with research, that is just another human venture, in Schön's wording a Reflection-in-Action[129]. "When someone reflects-in-action, he becomes a researcher in the practice context. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case. The practitioner doesn't keep means and ends separated, but defines these interactively as he frames the problematic situation."[130] The academic researcher has his methods and research questions defined and begins his work from there. Although, when one acknowledges Schön's distinction between research and practice, it is inevitable that the boundary between the two blurs when research touches emerging phenomena and things on the verge of realisation.

[127] Junestrand & Keijer, 2001, p. 71.
[128] Schön, 1991.
[129] ibid, p. 49.
[130] ibid, p. 68.

Finally, this work primarily deals with the *functionality of the artifacts*. The question about *how designed artifacts work in a social context* is not examined.[131]

3.5 Research Questions

The hypothesis is that there exists a specific modality of digital space related to the concept of the smart home. Further it is advocated that this modality is a relevant issue for the architectural profession and architectural research. The main objective for the current research work is formulated accordingly.

The leading question for the study is:

- How can spaces for video mediated communication be designed and integrated into smart homes?

From this principal question more specific points can be derived. Hence four more detailed research questions were formulated:

- What kinds of design concepts are relevant for the design and the integration of video mediated communication in the domestic environment?
- How can private and public domestic spaces, in relation to video mediated communication, be designed, considering functional aspects?
- Can formal methods be applied to describe the design and integration of video mediated communication in the domestic environment?
- Which domestic activities can video mediated communication appropriately support?

As mentioned previously, the general purpose has been to discuss, model and formulate the questions, and in parallel develop tentative answers in order to discern essential issues. The goal is not necessarily to find conclusive answers to the formulated questions, rather it is, from an architectural perspective, to develop the concept of VMC as

[131] For reading about how different designs work in the social context see for example Dant, 1999.

an essential artifact to be considered for the future in smart homes. The questions serve as guidelines for identifying crucial issues in the domain. Provisional answers to the questions will be provided and discussed in chapter six. Specific questions are developed in each of the papers.

These research questions were already roughly formulated at the beginning of the research. However, during the course of the research process, they have successively been refocused, refined and reformulated. These questions, if at least partly answered, should be of interest not only for the scientific community, but hopefully for the practising profession as well.

To conclude, this chapter has developed the scientific scope of the work, explained the rationale for the chosen point of departure and the process of focusing on a few central research questions.

In the next chapter an overview of related academic research is presented.

4 RELATED ACADEMIC RESEARCH

In this chapter the most relevant research for VMC in smart homes from an architectural perspective is presented. The research projects have been structured around three domains: the socio-cultural, the architectural and the technological respectively. Firstly, an overview of Swedish architectural dwelling research is presented with a focus on the years 1940-1960. This was a research period which became considered as very successful in its approach from a functionalistic perspective to new architectural problems. Although the problems and the situations now differ from the view and topics of that time it is fruitful to make it the starting point, both from the view that this period of time, in retrospect, is considered a period of substantial change in society, and from a methodological point of view, see also chapter 2 above.

4.1 Swedish Architectural Dwelling Research

Research around the early Swedish dwelling during the twenty years between 1940 and 1960 is considered successful in several aspects. Formulated goals were achieved. The research became important for building practice. Society as a whole was strongly influenced and the research had a large impact on dwelling design.[132] For example, guidelines and rules for the spatial distribution of the home, minimum spaces for different functions and rooms within the dwelling, as well as the placement of windows and doors were developed. Two main trends prevailed: the sociological-positivistic (represented by Lennart Holm and Carin Boalt) and the ethnological-history of art (represented by Börje Hanssen, Gregor Paulsson and Thomas Paulsson).[133]

"Good Dwellings, today and tomorrow"[134] can be seen as a condensation of the ideas and knowledge that Holm and Boalt and the group around them had collected by that time through empirical and methodological work.[135] "Holm contributed substantially by

[132] See for example Berg et al., 1952, Boalt & Holm 1966, Holm 1956 and Paulsson, 1960.
[133] Sandström, 1989, p. 134.
[134] Original title in Swedish: God Bostad, idag och imorgon, 1954.
[135] Sandström, 1989, p. 132.

adapting and improving dwelling research to the methodology applied in sociological research in general".[136] The problems with the construction of homes of that time should be solved by new scientific methods. Research, experiments and scientific argumentation should be the base for mapping and documentation of the needs of Swedish people concerning the dwelling. Sandström[137] further asserts that interesting results from this early dwelling research concerns both the development of methods and of concepts.

However, at some time during the 1960s the research became more technically oriented and successively less interesting as pure research. Scientifically the approach was not exhausted. The methods could be further improved and more refined, however in pursuing the ambition to imitate the discipline-oriented research the risk of losing the purpose of the research became obvious.[138]

A relationship between this dwelling research half a century ago and the research approach of the present work can be discerned. At that time the research area - homes in general - was virgin and unexplored. This is also the situation for today's research on VMC in smart homes. A big difference is that today a clear social ambition to solve dwelling problems for the population is lacking. Now it is left to the market to solve questions about new services and added values to the dwellings, some public needs are still of interest though, for example concerning disabled people.

A number of new research projects[139], basically within the same principal research paradigm, were carried out in the 1970s. The results were less instrumental. Whether some specific results were to be recommended before others became less obvious in comparison to the situation some decades earlier. "The refined statistical investigation methods often masked that the theories underneath were not equally sophisticated. The way to look at living at home went no further than what to a large extent was achieved in the initial thinking by the early functionalists. To dwell became to sleep, to cook, to eat and to

[136] ibid, p. 141. Original text in Swedish "Holm gjorde därmed en viktig insats i arbetet att anpassa och höja bostadsvaneforskningen till den allmänna sociologins metodnivå.".
[137] ibid, p. 127.
[138] ibid, pp. 166-167.
[139] See for example Gaunt et al., 1982 and Åhlund, 1976.

associate. The complex phenomenon of living was reduced to functions and activities that could be recorded".[140]

Although many good results were achieved, especially in the early years, it became obvious that a too narrow functionalistic approach could not be sustained over time. How to design and build for VMC in smart homes in the future should benefit from this lesson. To precisely prescribe how VMC should be applied in dwellings, at predefined settings, will not do. On the other hand, a functionalistic approach may advance basic knowledge in the field, and well monitored investigations will produce interesting results supporting further research, development, discussion and analysis rather than firm recommendations.

The result of this brief analysis of the early Swedish functionalistic movement offers hints as to how to handle new forceful artifacts like VMC to be used in homes.

4.2 Socio-Cultural Research

The use of technology in the domestic environment is a relatively unexplored area of definitive interest. Technical developments to be used in the home environment depend on the understanding and integration of the technology into life at home. Below some important research in this area is presented, starting with Swedish experiences.

4.2.1 Swedish Studies of Home Technology

Cronberg and Sangregorio did some early work on the use of domestic technology. In the report "Inside ones own doorstep, new technology and it consequences for lifestyle"[141] they describe three typical domestic processes: 1) washing, 2) watching TV and 3)

[140] Krantz in Thiberg (Ed.), 1985, pp. 100-101. Original text in Swedish "De statistiskt förfinade undersökningsmetoderna kom ofta att dölja att teorierna bakom dem inte var lika sofistikerade. Sättet att se på boendet kom i stor utsträckning att stanna vid de tidiga funktionalisternas funktionstänkande: Att bo blev att sova, att laga mat, att äta och att umgås. Det sammansatta fenomenet som boendet är reducerades till registrerbara funktioner och aktiviteter.".
[141] Cronberg & Sangregorio, 1987. Original title in Swedish "Innanför den egna tröskeln: ny teknik och dess konsekvenser för livsstilen.".

shopping and storage of food. The selected activities were studied from three different perspectives: that of the individual, of society and of the housing company. By applying historical analysis they showed how new technology supporting activities at home was introduced, and the resulting consequences. A typical result from their studies was that the total time spent on a certain activity – in this case washing clothes – was about the same as when they were washed by hand. On the other hand the clothes were washed a lot more often after the introduction of the washing machine.

Östlund studied the use of technology by older people and their attitude to it in everyday life in "A study of technology in older people's everyday life"[142] This is a collection of several projects all aimed at clarifying how technology is actually applied and integrated in to the practical and social life of older people, including their attitudes to it. The report shows that technology forms an important part of the lives of older people. Television and the telephone are typical examples. Basically, a positive attitude to technology was noticed. A necessity though, was that the use of it ought to comply with a personal set of values, and it must be easy to use; criteria equally valid for most users.

Figure 13. A Digital key evaluated in the IT-BO project. (Source: Junestrand & Keijer, 2000)

Keijer and Nilsson[143] have described the challenge of focusing on the user perspective in a dynamic process concerning the development of new ICT-supported services. The service providers, primarily the large telecom companies and utilities, have a very strong position, and the services are generally packaged on their premises. The genuine and unique possibilities to individual variations offered by ICT are seldom realised.

In addition to what is presented in this work, the Author has worked with different aspects of the use of existing and new technology in the domestic environment. Together with Ulf Keijer, an investigation was carried out which mainly treated the problem of how new ICT was received and used in the dwelling environment, see figure 13.[144] The services were evaluated with a model consisting of a mix of methods

[142] Östlund, 1995. Original title in Swedish "Gammal är äldst - en studie av teknik i äldre människors vardag.".
[143] Keijer & Nilsson, 1996.
[144] Junestrand & Keijer, 2000.

applied to a spectrum of measurement fields. The final discussion points out the importance of founding the ICT-supported services on existing and well-known functions in order to achieve user acceptance and frequent use.

The Author, together with Konrad Tollmar, presented several evaluation and design projects. A design framework for new communication media and the possibility of a holistic approach for interpersonal communication was discussed.[145] Different design activities were described of which *Virtually Living Together* aimed at a better understanding of how communication and information technology works in private life. A method called *Observation and Invention*, originally developed by IDEO[146] was applied. It is a scenario-based design method with early observations of real users in real contexts. Future characters and scenarios are developed on the basis of actual observations, and they will move the matter to a future use of a virtual system. Finally, metaphors are used to construct conceptual models. Early prototypes were developed from these conceptual models and other product ideas were born in the *Observation and Invention* project. A couple of these industrial design models have been taken into functional prototypes with further integrated technology by other participants of the research team, see figure 14.

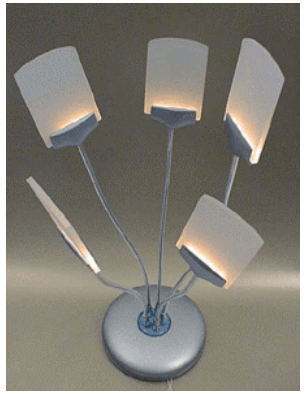


Figure 14. "6th sense" is a light sculpture developed in the project Virtually Living Together. Through telecommunication the light intensity of every plate responds to the remote fluid of electricity or water in the home of another family member or friend. (Source: Tollmar et al., 2000)

Brovall presented two reports on smart home technology based on seminars and discussions with end users, professionals and academics.[147] Both the comHOME flat and the video "Private and Public Spaces – the Use of Video Mediated Communication in a Future Home Environment"[148] were used as means for starting up interviews and discussions in seminars.

Sandström described the benefits of different kinds of IT-solutions experienced by residents in the smart homes.[149] The research objects were three building projects equipped with a number of IT-functions designed so as to increase safety and security, to offer improved

[145] Tollmar et al., 2000.
[146] Verplank et al., 1993.
[147] Brovall, 2000 and Brovall et al., 2002.
[148] Junestrand et al., 2000.
[149] Sandström, 2003.

comfort and to decrease housing costs. The central concepts in the study were *usability*, *benefit* and *accessibility*. Most appreciated functions are those which increase safety and security (e.g. alarms), save time (e.g. booking of common facilities) and increase comfort (e.g. sunshade control).

4.2.2 Understanding Technology in the Domestic Environment

Hughes et al. describes a holistic view of the role of technology in the home environment mainly from a sociological point of view.[150] The authors argue that the impact of new technology in the home environment is increasing. They found that the presence of technology in the home is absorbed so completely into the routines of home life that it becomes yet another way in which these routines can be articulated.

The authors conclude that the role and importance of technology in the dwelling process is increasing. The technological configuration of the home often reflects family routines, and the technology is ordered in a way that supports and facilitates them.[151] However, technology is not applied in everyday life without problems. On the contrary, the context of home activities is generally strict. The activities are constrained by explicit or tacit rules, and stress was induced by rearrangements associated with technology changes.

4.2.3 The National Outlook for Automation in the Home

Venkatesh and his research colleagues at the University of California, Irvine, do research on ICT in the home environment mainly from a sociological point of view. Their project NOAH (The National Outlook for Automation in the Home) tries to uphold a holistic view of the role of technology in the home environment. The main objective of their study is to examine the use of new media and information technologies in the home and their impact on family life and home-based work life. The study examines the design aspects of new technologies as well as the design of home environments where the technology is to be used.[152]

[150] Hughes et al., 1998.
[151] ibid, p. 255.
[152] Venkatesh, 1999, p. 216.

The authors have identified four stages in the evolution of home technology over a period of time: the *electrification* stage, the *automation* stage with the introduction of electricity and electrically powered appliances in to the home, the *intelligentification* stage where simple programmable and automated machines were introduced, and the *human substitution* (robotics) stage (which is the current stage) where intelligent and programmable machines are being introduced. The latter is also the stage when home communication systems develop most quickly. The prediction for the next stage is the introduction of home robots; in the beginning relatively simple ones, though successively they will be more advanced. The home is becoming "the centre of gravity" because of its evolution from an isolated social entity into a socially connected virtual organisation.[153] As a living space, the home varies from time to time. Historically it has changed its character and it will do so again in the future. A particular concern is how technology fits into the home as a living space. In order to address this complex issue, the living space is subsumed into three distinguishing components: the *social space*, the *technological space*, and the *physical space*.[154]

4.3 Technological Research on VMC and Smart Homes

An increasing number of projects focusing on smart home research are built as full scale models, predominantly prototypes. However in some cases they are implemented in real life environments. Most serve both as a laboratory and as a showroom. VMC as a specific technological application has been implemented in several full-scale projects and real life testing has been carried out. Some interesting projects of this kind will be briefly described.

4.3.1 Smart Bo – a Smart Home for Disabled People

An important research and development domain of smart homes is oriented towards the needs of disabled people. In Sweden the SmartBo project was carried out during 1999-2001.[155] SmartBo was a groundbreaking project focused on the integration of new

[153] Venkatesh, 2001, pp. 3-4.
[154] ibid, p. 10.
[155] Elger, 2002.

Figure 15. User interacting with the Smart Home in SmartBo. (Source: Videoclip in CD 2 "SmartBo - en bostad för alla" in SmartBo, Hjälpmedelsinstitutet)

technologies supporting independent living for people with a variety of disabilities. SmartBo was not designed for real living, the project rather served to show real working solutions for end users, namely, disabled people and their families on the one hand, and researchers and practitioners on the other. The aim of SmartBo was to compile knowledge and establish competence about how ICT could be used in order to offer enhanced independence in the lives of disabled people. SmartBo demonstrated how different functions in the home could be either automated or controlled by people with severe disabilities of different kinds, such as physical, sensory, and cognitive, see figure 15.

The SmartBo project was closed in 2002. Resulting experiences were brought into the development of SmartLab, a full scale demonstration flat and meeting place at the head office of the Swedish Handicap Institute.

4.3.2 House_*n*

House_n[156] is a multi-disciplinary project led by researchers at the Department of Architecture[157] and the Media Lab[158] at Massachusetts Institute of Technology (MIT). House_n is a full scale two-bedroom condominium "living laboratory" in a residential building with the intention of forming a research facility where new technologies and design concepts can be tested and evaluated in the context of everyday living, see figure 16. It is intended to be a highly flexible and multi-disciplinary research facility designed explicitly for studies of people and their patterns of interaction both with technology and with the home environment.[159] A multitude of sensing components are installed in nearly every part of the home to be used in order to develop innovative user interface applications aiding people to easily control their environment, save resources, remain mentally and physically active, and stay healthy. The sensors will also be used to monitor various events in the environment and people's reactions to these events in the complex context of homes where various architectural designs are also to be implemented and studied.

[156] http://architecture.mit.edu/house_n/web/index.html [2004-08-06].
[157] http://architecture.mit.edu/expo.html [2004-08-06].
[158] http://www.media.mit.edu [2004-08-06].
[159] http://architecture.mit.edu/house_n/web/placelab/livinglaboratory.htm [2004-08-06].

House_n will be used to evaluate digital and physical infrastructural concepts and to host ongoing research as a "living laboratory". The ambition is to create a modular and highly flexible house allowing a variety of architectural ideas, new materials, new constructions, new systems, and new applications to be tested over time. The focus of the research at the House_n project is on activity recognition and interaction with the environment supported by ubiquitous video communication.[160]

Figure 16. Image of the construction of the House_n laboratory to be constructed near MIT. (Source: http://architecture.mit.edu/house_n/web/placelab/livinglaboratory.htm [2004-08-06])

4.3.3 The Aware Home Research Initiative

The Aware Home Research Initiative (AHRI)[161] is an interdisciplinary research initiative undertaken at the Georgia Institute of Technology that addresses the challenges facing the future of domestic technologies. A unique and critical resource for this activity is the Georgia Tech Broadband Institute Residential Laboratory, a three-storey, 450 m^2 home lab, functioning as a living laboratory for interdisciplinary design, development and evaluation.

Several interesting activities are being developed here. Of special interest is the "Indoor location tracking project", which defines its own task in this way "Location is an important clue as to what a person is doing in an environment. Providing this information should be one of the cornerstones of creating an environment that perceives individuals interacting in the environment".[162] The research question guiding the work is formulated: Is it possible to create a home environment that is aware of its occupants whereabouts and activities? If we build such a home, how can it provide services to its residents that enhance their quality of life or help them to maintain independence as they age?[163]

What the research team means is that more appealing applications would be introduced if more precise location information could be provided. It should be more fine-grained than at "the room level", i.e. "in-room" or "not in room". It should have the ability to tell where

[160] e.g. http://www.media.mit.edu/~intille/papers-files/TapiaIntilleRebulaStoddard03.pdf [2004-08-06].
[161] http://www.cc.gatech.edu/fce/ahri [2004-08-06].
[162] http://swiki.cc.gatech.edu:8080/ahome/129 [2004-08-06]
[163] ibid.

someone is located in the room. The laboratory is fitted with cameras in the ceilings, enabling overhead views, see figure 17.

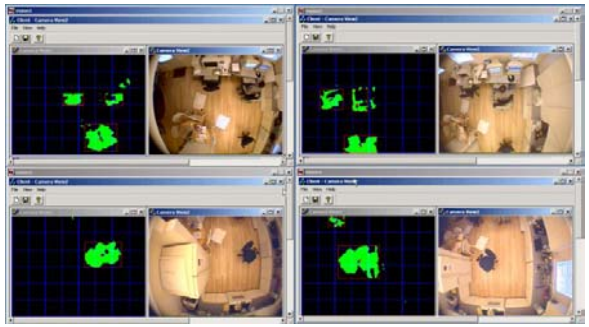


Figure 17. Screenshots of tracking software. Top camera views to the right in every screenshot and a digital analysing of the positioning to the left. (Source: http://swiki.cc.gatech.edu:8080/ahome/129)

4.3.4 VMC and Human Interaction

Huang et al. performed practical studies of VMC and its social and psychological implications.[164] They found that proximity between people affects the interaction when using VMC systems. People near each other seem to speak more informally. Conversations using VMC influenced social dynamics in various ways, e.g. a tall individual seemed to dominate more in a social interaction than an apparently short person. Yet, with VMC, such characteristics may be displaced by technological arrangement, for example, by the camera angle or the placement of the monitor. The authors recommend caution at the use of VMC, in order, as far as possible, not to distort an interaction on equal terms.

Other important aspects and qualities of VMC systems are underlined in several research projects. For example, according to Whittaker it is well known that non-verbal communication cues play an important role in social interaction.[165] If a system is considered able to

[164] Huang et al., 2002.
[165] Whittaker, 1995.

automatically understand a communication, it not only has to analyse the verbal content of a discussion but it also has to keep track of visual cues such as gestures, gaze and facial expressions of the participants. In their research they pay specific interest to tracking whom or what a person is looking at during a communication session.

4.3.5 VMC and Computer Shared Collaborative Work

Tollmar[166] carried out work related to VMC in the public office environment within the research domain of Computer Supported Collaborative Work (CSCW). Studies of video communication indicate that the predominant contribution to the communication process of the video medium in comparison to a telephone call is its richness regarding social context, and that video is well suited for informal communication.[167] [168] It is also likely that informal network building and maintenance will become more and more important for individuals when an increasing part of professional work is carried out at home. The principal contribution by Tollmar et al. is the physical establishment of so called VideoCafés in different spatial and technical set-ups, see figure 18. The VideoCafé is a place for informal meetings in the media space between co-workers at different locations.

Figure 18. The VideoCafé set up in use, three students at the CID research centre, KTH, communicate during a coffee break with researchers at the remote Ericsson MediaLab which has a similar set-up. (Photo: Konrad Tollmar)

4.3.6 Generating Media Spaces

Bellotti & Dourish[169] describe how the design of a media space system can be seen not just as a substitution for physical co-presence, but as a means for providing new resources for communication and collaboration. Their contribution is based upon a long-term study of the use of a network of audio, video and computing technology both as a study of the phenomenon as such and as an infrastructure to support daily activities. They underline that media spaces are not based around a "telephony" model of communication involving only explicit "call-style" connections. On the contrary, cameras and monitors and systems sensing electronic events are "turned on" continuously, providing accessibility to public and personal spaces.

[166] Tollmar et al., 1998.
[167] Kraut & Fish, 1997, in Finn et al., 1997, pp. 541-559.
[168] Tang & Isaak, 1993.
[169] Bellottti & Dourish, in Finn et al., 1997, pp. 245-272.

Although facial expressions, gestures, side conversations, and intonation are important aspects of a working dialogue, the ability to see and be seen and, for example, to speak to one another on the same side of the communication line whilst being watched by people from the other side, are enriching components of media space environments.

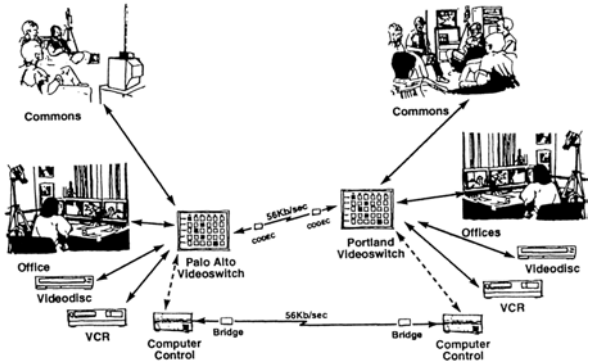


Figure 19. The PARC Media Space linking offices, open areas, and audio-video services in Paolo alto and Portland. (Source: Harrison et al., in Finn et al., 1997, p. 276)

Activities of the kind mentioned above form the basis of a "work community" according to Harrison et al.[170] The authors describe, from a technical perspective, a media space set up between two remote offices belonging to Xerox Palo Alto Research Center (PARC), see figure 19. They found, amongst other things, that coordinated audio and full-motion video together, can extend the physical world to include people and events taking place elsewhere. The physical and technological attributes of a media space create a space that is as real as, but different from, the everyday office environment.[171]

Harrison et al. mean that media space is a kind of space in itself. It is like the notion of a "theatrical space" when a play is performed. The conventions of the theatre take over, time and place are dictated (or at least strongly suggested) by the play. media space is a construction that brings disparate places and times together in a physical space. "Miles and time zones are swallowed by coax and electrons, the melting pot of the photospheres becomes a site for new rituals".[172]

[170] Harrison et al., in Finn et al., 1997.
[171] ibid, pp. 273-275 & p. 283.

4.4 Research on Architectural Design and Smart Homes

As seen so far, a lot of research is and has been performed about interactive systems and artifacts both for and in the home. However, little research deals with the design of smart homes from an architectural perspective. Some interesting exceptions exist though and will be briefly explored below.

4.4.1 Furniture Arrangements

The arrangement of furniture is a basic issue when studying the use of technology in the home. The furniture arrangements alter over time due to changing needs and habits. These habits have themselves been changed by the introduction of new technology and new mediating equipment in homes. Torgny[173] studied how different media forms change everyday domestic activities. The key question was: "How can new IT technology be practically integrated into the domestic environment and social activities? And how is the home as concept and space affected by new information technology?"[174]

The project has been carried out using different creative methods,for example, brainstorming. A structured method for generating, and later for illustrating different scenarios and situations was evaluated, see figure 20. This method offers a quick overview of qualitative problems and dynamic processes, but requires well formulated boundaries and criteria. It is concluded in general terms that ICT can support and encourage social domestic activities and enrich existing activities and products in homes. As a consequence this will affect the internal arrangements of our homes.[175]

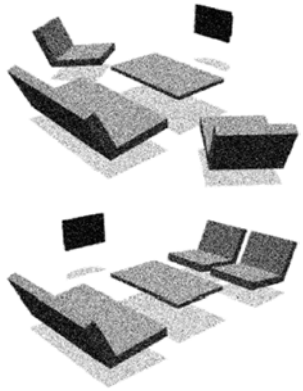


Figure 20. Above: Sitting room furnishing – all watching TV. Below: Sitting room furnishing – for social interaction and TV. (Source: Torgny, 1997, p. 46)

[172] ibid, pp. 282-283.
[173] Torgny, 1997.
[174] ibid, p. 7.
[175] ibid, pp. 51-52.

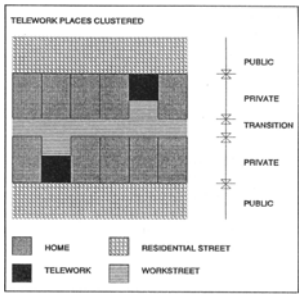


Figure 21. Proposal to spatial organisation of the dwelling in the neighbourhood by Caso & Tacken. (Source: Caso & Tacken, 1993, p. 35)

4.4.2 Relationship between IT and the Built Environment

Caso and Tacken[176] studied spatial aspects and relationships between IT and the built environment. New technologies are discussed and classified in a structured manner resulting in schematic floor plans. The aim of the work was primarily to classify different ICT supported activities and their inter-compatibility in time and space. The work is entirely theoretical. The authors suppose that - on a large scale - ICT will be introduced into the areas in and around the dwellings and that it will affect the processes of living at home. Such an introduction of new ICT must be supported by a new design and a new organisation of the dwelling and its neighbourhood[177], see figure 21. Their work includes an analysis of the compatibility between a number of identified home-related activities in time and space. The work concludes with a programme containing guidelines for the spatial organisation of the dwelling and the neighbourhood.

The work of Caso and Tacken could be criticised for not taking into account the dynamic character of ICT. Their assumption that many of the activities have to be performed at fixed places in the home is obsolete. Today, the fixed connections could easily be replaced by wireless communication devices to the user's convenience. The size of the equipment is becoming smaller with more functions and new designs. This offers a flexibility and mobility that was easy to overlook some ten years ago.

4.4.3 The Smart Apartment Building (SAB)

The SAB (Smart Apartment Building) is a "real life laboratory" housing project for the development of multimedia services for the home environment in the city of Hilversum, Holland. SAB focuses on the contribution of ICT to the quality of life and to sustainability, as being expressed in new planning concepts of the home environment, see figure 22. The question underlying this initiative is: How can ICT - and in this case multimedia - change existing processes in our society in such a way that it benefits everyone? This question led to the assumption that ICT affects and changes the use of space and thus the desired layout of the houses we live in. ICT may contribute

[176] Caso & Tacken, 1993.
[177] ibid, p. 29.

substantially to the spatial convergence of living, working and recreation, whereas these functions have been quite separate in traditional planning.

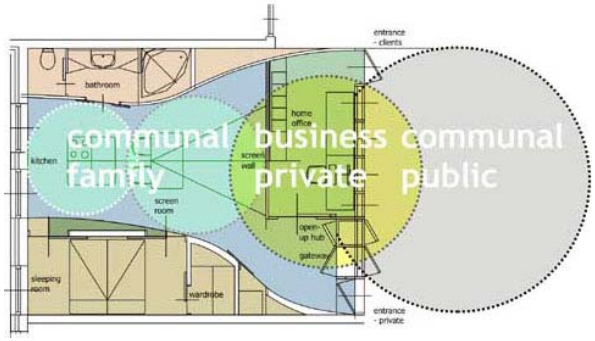


Figure 22. Floor-plan scheme of a flat in the SAB project, with the three social zones communal/family, business/private and communal/public. (Source: http://www.unstudio.com [2004-08-06])

Related to the SAB, van dePas and Frissen carried out a case study as researchers involved in the project. The most interesting question addressed concerned the relationship between ICT and space and how this relationship materialised in this specific project.[178] Does it show? How does it show? Can it be assessed? A combination of research methods was used to work with these questions, including participant observation, interviewing and analysis of basic documents and contextual data. A conclusion was that ICT and multimedia can be conceived as a pivotal element to realise what was called "interpretative flexibility", increasing the users' potential to define and give meaning to their own home environment. They also mean that the characteristic of new ways of living is exactly the blurring of boundaries between separate functions, and that ICT both enables users to cross these boundaries and gives them a means to redefine the boundaries. In this case, “quality of life” implies that new lifestyles, new patterns of activity and new needs can be met by a living environment offering its inhabitants control and flexibility.

[178] http://www.spectreproject.net/vervolg/vervolg2/pdf/SMART%20LIVING.pdf [2004-08-06].

4.4.4 Everyday Spaces

Thomas Wikström studied how ICT, and especially the development of media, changes the everyday spaces and the concept of space. In the development of new media today there is a strong interest in space and the use of it, i.e. the space where our body proves to be and simultaneously the space where our mind turns out to be.[179] The dwelling has always been, and still is, such a place. The media space develops its own autonomy and becomes an alternative reality that simulates, or substitutes, the concrete space, in a world where we also can meet in a new, virtual character. This exists even to the degree that people are at risk of being absorbed by this virtual world in their games, collective fantasies and social meeting places, and that their presence in the real world gets disempowered. [180]

Wikström also deals with the concept of local and global place. When the information and communication technology connects into global networks, distance loses its importance. Actions and interaction are prolonged far beyond the physical space and reach out globally. These are places where people meet daily, and where social interaction develops, now considered a prerequisite in public life, from the global to the local. Today more than ever, these places are connected. Direct face to face meetings are combined with the flow of information and possibilities of communication that digital medias permit, and parallel local and global actions, within the same space, become reality. The physical space, both at home and at work, gets filled with signals and messages from other places that call on our attention and sometimes totally absorb us.[181]

This chapter included some significant research related to smart homes and VMC. One may notice that the architectural perspective is present all the time. However it is often not explicitly handled by educated architects. Other professions seem, to a considerable extent, to work in areas and discuss issues that typically are central topics for the architectural profession.

[179] Wikström, 1998, pp. 8-12.
[180] ibid, p. 270.
[181] ibid, p. 4.

5 THE COMHOME FLAT AND PAPERS CONTRIBUTING TO THE THEME

Five papers, reprinted and included, form the central contribution of this thesis. All papers are related to different research undertakings to which the Author has made substantial contributions. Below the content of each paper the research questions are emphasised and the methods employed are described. As all the papers have two or more authors, a review of the Author's specific contribution for each paper is made. The papers are ordered in chronologically.

Firstly, however, a description of the background, the design and the building process of the comHOME project is given. This could be regarded as a base for all the particular research presented in the papers and yet its development is not explicitly covered in any of them.

5.1 comHOME – Background, Design and Building Process

The comHOME flat is a full scale smart home with integrated video mediated communication (VMC) built both as a laboratory and as a showroom at the Telia headquarters facilities at Farsta, Stockholm. It is not a fully-fledged flat, but it contains important requisites able to simulate key processes related to home life. The comHOME flat is used in all tests and evaluations reported in this study.

5.1.1 Background

The project started at a research laboratory in the premises of the leading telecom operator in Sweden, Telia AB, called S-lab (subsequently referred to as Telia). Telia had in the mid 1990s developed a technology for providing cheap broadband connections for multi-family houses. There was a need for a combined research laboratory and showroom for this novel technology. Telia's question was: What can you do with a bit rate of 100 mbit/s in your home? During 1997 several workshops were held at Telia[182] in order to develop ideas and conceptual applications to be tested in the new

[182] With representatives form Telia, Ericsson MediaLab and CID.

research lab. CID[183], where the Author worked, presented to Telia an idea about constructing a full scale smart home flat with integrated VMC applications in the new laboratory and showroom. The staff at Telia appreciated the approach as it seemed to allow the realisation of valuable everyday applications taking advantage of novel powerful communication technologies. At the same time they assumed it could lead to a positive and exiting image of the project for internal and external promotion. The Author was assigned to lead the project from the CID side.

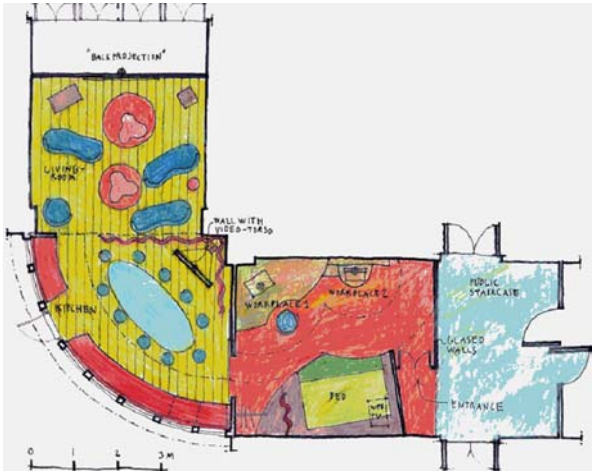


Figure 23. Floor plan sketch of the comHOME flat. To the upper left is the living room. The room at the lower left is the kitchen. The middle room at the bottom is a combined telework and bedroom. At the lower right is the entrance of the buildings public staircase, which does not form part of the flat. (Source: Junestrand & Tollmar, 1999, Paper 2)

The available space for the building of the flat was limited to a former reception area of 3 rooms totalling approximately 50 m2, located in direct connection to the public staircase on the bottom floor of the office building. A square room was located closest to the public staircase with an old reception desk. The room in the middle had a

[183] Centre for User Oriented IT-Design at KTH, Stockholm.

square corner and a curved wall that ran from one diagonal corner to another with windows and a terrace door facing a closed outdoor garden. The third room had no windows and was connected to a server room for the laboratory. Figures 23 and 24 depict the spatial organisation of the flat according to the proposed design. The difference from its final realisation is insignificant.

5.1.2 Design

The basic design idea of the flat was to create a smart home with different zones for video mediated communication, comZONES[184], to support the demands of both private and public digital spaces related to the use of video mediated communication (VMC).[185]

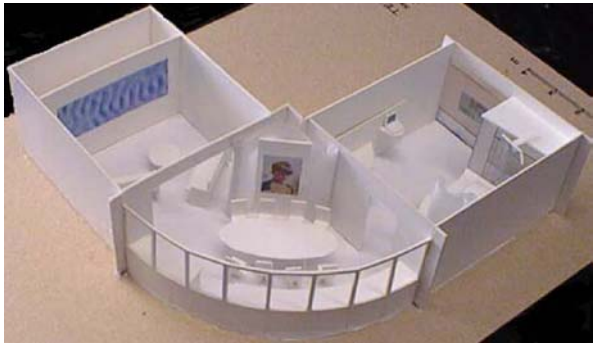
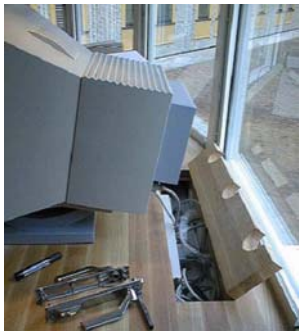


Figure 24. A model of comHOME before its construction. At the upper left, the living room with the mediaSPACE wall, and the space for the back-projection video projector equipment behind. In the middle, the kitchen with the windows and the kitchen workplace, the table and the videoTORSO. To the right, the combined telework and bedroom, with the glass wall to the public staircase at the end. (Model and Photos by Ines Leal and Stefan Junestrand)

The design of the comHOME flat and the different comZONES was strongly influenced by the space provided for the construction. The creation of a bedroom combined with a place for telework was

[184] The concept comZONES is developed by the Author and is an abbreviation of "communication zones".
[185] The original idea of zones for different communication modes was first described in Junestrand & Tollmar, 1998, p. 245 (Paper 1).



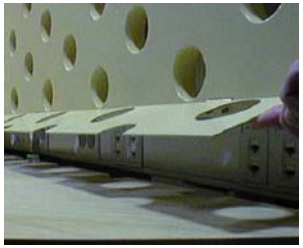


Figure 25. The interior of the comHOME flat. Above: The hidden outlets in the kitchen. Below: The hidden outlets in workplace in the combined telework and bedroom. (Photos: Stefan Junestrand)

decided upon early in the design process, as it brings to the edge possible conflicts in time between the different activities and questions about being private and public at home. The combined telework and bedroom was located in connection to the main entrance staircase of the building and separated with just a glass wall with a door. In this way the research lab and showroom became exposed to the public and easy access was provided for visitors to the comHOME flat. The workPLACE was located at one side of the room with the bed placed opposite to it. A sliding door separated the combined telework and bedroom from the kitchen. All working space and equipment in the kitchen was located at the curved wall with windows providing natural daylight. The central part of the room was arranged for the comTABLE and the corner was supposed to be an ideal place for the videoTORSO. Between the kitchen and the living room a heavy motorised curtain was placed in order to be able to separate the two spaces acoustically and visually. At the end of the living room a place was created for the back-projection video projector equipment behind the mediaSPACE wall, see figures 23, 24 and 26.

The comHOME flat was aimed at demonstrating different spatial scenarios and was not built as a complete dwelling, in that it lacks a bathroom, basic space for storage, it has a glass wall in the bedroom, and neither the bedroom nor the living room have any windows. The technological equipment, such as cabling, outlets, speakers, ventilation systems, and so on, were, to a large extent, built in or hidden, see for example figure 25.

5.1.3 Building Process

In addition to the researchers from CID and staff from Telia, a team of professionals was involved in the building process including an architect[186], an interior decorator, a systems integrator, an HVAC consultant, a civil engineer, and a representative of the real estate company.

[186] The actual drawings or specifications where not realised as a part of the research activity. Leal & Junestrand Architects did the actual architectural consultancy work for Telia. The Author was not the responsible architect, but participated in some of design work as an advisor.

The design of the comHOME flat started in January 1998, and the construction work late in the spring. Initially, the walls separating the spaces where removed, likewise the interior and the main part of the electrical and heating installation. The new electrical installations were fully equipped with home automation technology for local and remote control of all electrical installation such as lighting, outlets, motorised blinds and curtains. High speed Ethernet connections were installed with multiple outlets plus new heating and ventilation. New walls, false ceilings and floors were constructed. Finally all the furniture was provided. The building process was finished in the spring of 1999 and a variety of experimental undertakings started. A few of these are part of the present study and are included in the papers. A brief introduction of each contribution is given below.

Figure 26. Photos from the interior of the comHOME flat. Above left: Looking from the glassed entrance into the combined telework and bedroom towards the bed, the workplace to the right and the kitchen in the doorway. Above right: The fully equipped kitchen, with the bedroom at the other side of the doorway. Below left: Looking from the living room towards the kitchen. The white box on the left is the back of the videoTORSO. The comTABLE is in the centre of the room and behind it, the kitchen equipment with the windows facing on to the inner garden. Below right: Looking from the kitchen towards the living room, with the curtain in the foreground on the right hand side, the furniture in the middle, the sliding door leading to the server room to the left, and the mediaSPACE video wall in the middle, with built-in speakers and spaces above the screens for cameras. (Photos by Stefan Junestrand)

5.2 Summary Paper 1

Stefan Junestrand and Konrad Tollmar wrote the paper "The Dwelling as a Place for Work", see further Paper 1.

The purpose of the paper was to describe some relevant aspects of how future residential architecture could be developed, and how communication technologies could be integrated to support co-operative work and similar activities in a domestic environment.

The paper discusses a number of basic architectural concepts, for example, space, time, private and public. The methods applied were mainly literature studies. The paper introduces an embryonic theoretical framework for subsequent work concerning both forthcoming papers and projects.

The Author was the principal person responsible for developing the chapter on "Architectural Concepts". Otherwise the paper was developed jointly by the two authors except for the chapter "Basic Communication" where the co-author took the principal responsibility.

The main contribution of this paper to the theme of the present thesis is the description of the basic architectural concepts and the introduction of the idea of different zones with different modes for remote communication.

5.3 Summary Paper 2

Stefan Junestrand and Konrad Tollmar wrote "Video Mediated Communication for Domestic Environments - Architectural and Technological Design", see further Paper 2.

The paper presents different theories and practical solutions for the integration of video mediated communication (VMC) into the smart home environment, primarily considering architectural and technical aspects. The paper contains a comprehensive description of the design ideas and solutions for the comHOME flat, a full-scale model of a "flat of the future", showing innovative architectural and technical designs with regard to the integration of VMC into the domestic environment. A number of so called set-ups for VMC are presented, e.g. the

"VideoTORSO", "the comTABLE", the "desktop and laptop workPLACE", "internetTV", and the "mediaSPACE". The principal problems dealt with are the different aspects of private and public zones that become apparent with the introduction of VMC in the home environment.

The predominant methods used for the design of the flat were sketches, models, technical descriptions and drawings. Literature studies were applied for the theoretical work.

The Author was responsible for the architectural and conceptual design of the comHOME flat and also for the description of the project in the paper. The co-author contributed mainly with technical ideas and issues concerning social aspects.

The principal contribution of this paper to the theme of the thesis is the introduction and description of the comHOME flat and the so called VMC set-ups with the design of the different aspects of the private and public zones.

5.4 Summary Paper 3

Stefan Junestrand, Konrad Tollmar, Sören Lenman and Björn Thuresson constituted the team behind the writing and production of the video-paper "Private and Public Spaces – the Use of Video Mediated Communication in a Future Home Environment", see further Paper 3.

The video-paper presents the so called comHOME project in a somewhat unusual manner. It comprises a written paper of two pages and a seven minute video film presenting every-day domestic scenes, the latter is the principal part of the contribution. The video displays scenes of a family living in the comHOME flat. It is based on scenarios of everyday domestic activities like professional work, cooking, dining and participating in social activities, all supported by video mediated communication (VMC) in various ways. The principal issue proposed in the comHOME project concerns different aspects of private and public spaces using VMC, a theme developed in the video. An important observation from the process of the recording of the video is that it is a very good complementary method in a complex design process, not least because of its focus on the user

perspective. The video proved to be a very good tool for interpersonal communication of the ideas proposed and explored in the project between the members of the research group and others closely related to the work.

The Author was the principal researcher responsible for the idea, the planning of the undertaking and the writing of the script for the video, as well as the writing of the paper. Thus the paper could be fully attributed to the Author, however, acknowledging the very active interpersonal exchange of ideas and criticism amongst the team members which constituted a strong intellectual environment. A professional film crew did the actual production of the video.

The principal contribution of this paper to the theme of this thesis is the demonstration of specific VMC set-ups in real life situations. The video film shows the use of the technology in realistic every-day-life situations and has proven to be an effective tool for the communication of the intended functionalities of the designs.[187]

5.5 Summary Paper 4

Stefan Junestrand, Ulf Keijer, Göran Molin and Konrad Tollmar developed the paper “User Study of Video Mediated Communication in the Domestic Environment with Intellectually Disabled Persons”, see further Paper 4.

The paper presents a user study of video mediated communication (VMC) involving six people with mild to moderate intellectual disabilities. The study took place at the comHOME flat. Two of the comZONES of the flat were tried and evaluated, namely the videoTORSO in the kitchen and the workPLACE in the combined bedroom and home office. The purpose of the study was, at an early design stage, to get a deeper understanding of how people use the specific comZONES set-ups.

[187] The video has been used in many presentations by the Smart Studio, Interactive Institute and CID to illustrate what kind of work they perform and projects they carry out. Also many of the Author's research colleagues have communicated that they repetitively use the video in the classes they give to their students related to architecture and Smart Home design.

The governing method applied to the study was video recorded observations. The observations were carried out around two different set-ups. In each of these set-ups the users had to perform certain tasks aimed at making the individual use the VMC systems and some of its functions, with a distinctive regard to spatial recognition and design.

The final discussion points out that the comZONES seemed to be interpreted correctly and to function aptly in relationship to the participants of the study.

The Author was the principal responsible for the planning and completion of the study and the main part of the paper. Molin's contribution regards the specifics about the classification of persons with cognitive disabilities, while Tollmar added some details about the applied technology. Keijer revised the paper before submission.

The principal contribution of this paper to the theme of the thesis is the experience from real use of the VMC-setups that has given valuable input to the design of the comZONES set-ups, both concerning technological functionalities and architectural design.

5.6 Summary Paper 5

Stefan Junestrand, Ulf Keijer and Konrad Tollmar are the authors of the paper “Private and Public Digital Domestic Spaces”, see further Paper 5.

"Pattern Language” is a way to describe architectural design concepts in a systematic and structured way, developed by the architect Christopher Alexander in the 1970s. The paper’s intention is to describe the application of Design Patterns as a method for analysing and solving new problems encountered at the introduction of information and communication technologies in homes. In the paper, Pattern Language was introduced and applied to the comHOME flat.

The purpose was to apply a selected formal (and architectural) method for handling problems systematically concerning the concepts of being private and of being public at home, specifically in connection to the use of video mediated communication in the smart home environment. The presentation formally follows Alexander’s structure in five cases all related to the design of the VMC artifact. It

starts with a number of concrete user situations related to human-computer interaction. Social and communicative phenomena or possibilities end up in new design patterns.

The principal contribution of this paper to the theme of the thesis is the formal and structured description of each one of the comZONES adapted to a proven architectural theoretical framework. The theoretical and methodological approach was developed by the Author together with Ulf Keijer. The Author has been responsible for the development of the underlying design of the comHOME flat and the specific patterns presented in the paper.

To conclude, this chapter presents five core papers of the work forming the essence of the overall thesis. They all have a relationship to the overall theme, namely that of being private and public at home in connection with the new artifact, VMC.

The next chapter proceeds with the identified and examined results from the work. Results, however, from this type of investigation cannot be clear-cut and decisive. The findings principally should be regarded as indicative, platform-shaping, and enabling a deeper understanding of the matter, serving as a basis for further discussion.

6 RESULTS

The theme for the present study "Being private and public at home - An architectural perspective on video mediated communication in smart homes" is wide and comprehensive. As a scientific area it is unexplored. Besides its obvious relationship to architectural research, especially to investigations related to dwellings and homes and their design and use, its technological and social contexts cannot be disregarded. The overview of the theme of the study in chapter 1, the examination of some principal prevailing perspectives in chapter 2 and the attempt to define a viable scientific base for the study in chapter 3, all serve as a support to facilitate the orientation over the field of investigation. This structure and analysis is instrumental when discerning the findings of the particular contributions to the theme in the five papers, and of the presentation as a whole. Chapter 4 offers additional background information through an overview of relevant academic activities undertaken in universities and research laboratories. These introductory chapters may be regarded as results of their own, at least as points of departure for the design of other experimental investigations, and also for future discussions, as will be pointed out and further commented upon.

The results are structured into five specific topics. Each topic is directly related to one of the five research questions stated in section 3.5. After the title, each topic is followed by the related research question. The five research questions are analysed and commented upon and where appropriate references are made to the results in the papers, 1 to 5. The contribution of each paper to the general theme is thus clearly demonstrated. The five topics are:

- Public Digital Space
- Design Concepts
- The Design of Private and Public Spaces
- A Formal Method to Describe the Design
- VMC Supported Domestic Activities

6.1 Public Digital Spaces

- How can spaces for video mediated communication be designed and integrated into smart homes?

There are two governing perceptions of space in the design and integration of video mediated communication into smart homes, the conception of *private* and *public space* and the idea of *physical* and *digital space*. A principal result from the study is that the interrelationship between these two perceptions of the architecture becomes crucial when VMC is considered for smart home applications. This result is developed below.

Returning to the earlier discussed epochs and their relationship to time - the agricultural age, the industrial age and the information age – at least as concepts to be used metaphorically, it will be possible to forward the proposed result in a more distinct way. Simplifications are made, justified as being just tools for the discussion and not as valid statements as such.

Thus, in agricultural society, design of the domestic space concerned physical spaces. The planning task concerned the separation of the private space from the public space, see figure 27 a.

In homes of the fully developed industrial society, artifacts like the TV, PC and the music entertainment system had to be considered for the home lay-out and interior decoration to a considerable extent. The digital space with images from television, video and PC games challenged the previously universally prevailing physical space. Although the telephone was there, the public digital space related to the home was not present, see figure 27 b.

In the fully developed information society, and with the integration of VMC into the home, public digital space is introduced. The use of the dwelling is expanded and so are the requirements on the design of the spaces. Thus, the home designer has to consider the character of private and public space both for physical and for digital spaces, see figure 27 c below. Unconditionally, this shift will increase the complexity of the design of the smart home and raise entirely new questions. This particular observation should be regarded as a genuine novelty.

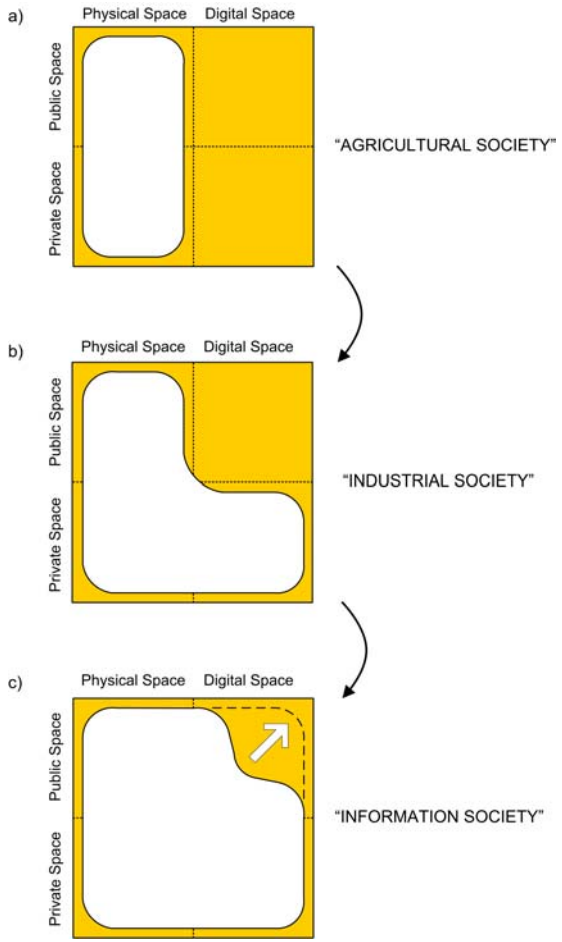


Figure 27. Illustration of the increasing complexity of spaces in the dwelling during various periods, the Agricultural Society, the Industrial Society and the Information Society.

Paper 1 introduced the concept of the private and public space. The concept of public and private spaces was developed during the industrial age and became really important. The private, eventually, became absolutely private and the public totally public. The public character of the traditional farmer's house disappeared in 20th century housing, which generally was intended for the industrial worker and his small family. Paper 2 introduces physical and digital spaces and how these have tended to be conceived as existing simultaneously.

Papers 2 to 5 address further different aspects of interpretation of the spatial concept presented above, in particular the extension of the space concept in the information society. This is a phenomenon with a variety of implications that it is not possible to fully grasp within the framework of this study. The papers describe some of these implications. However they represent only a fraction of possible investigations. This research field remains principally uncharted.

6.2 Design Concepts

- What kinds of design concepts are relevant for the design and the integration of video mediated communication in the domestic environment?

Several design concepts for the integrating of VMC in the domestic environment are presented and developed in this work. They all have pursued the idea of introducing some technical equipment associated to one or several functions and in combination with a specific architectural design idea. These realised concepts are called “comZONES”. Another more generic concept used is "VMC set-ups".

Paper 1 ends up with the idea of creating an architectural design solution for the distribution of video mediated communication throughout the home by dividing the space of the dwelling into different zones. Each zone is designed to offer an intuitively clear communication mode. The zones may vary regarding their forms and functions over time.

Paper 2 presents the design and development of the comHOME flat. The governing design concept was the development and integration of comZONES, even called VMC set-ups. These comZONES were

distributed throughout and integrated into the flat. The paper pays attention to the aspect that an added value to dwellings seems to be offered if information technology and architecture mutually interact in supporting the integration of VMC. The different comZONES support the demands of both private and public digital spaces within the home environment. In an inner zone, a person can be both seen and heard through the VMC equipment. In the middle zone the user can be seen but not heard. In the outer zone a person can neither be seen nor heard. In this way the inner zone is a public zone, the middle zone is semi-public and the outer zone is a private zone. It is of interest how the outer world is perceived from within the home through VMC, as well as how the dwelling, supported by VMC, is perceived from places outside the home.

In paper 3 the design concept with the comZONES is presented in video film format. The selected comZONES were the videoTORSO, the comTABLE, the workPLACE and the mediaSPACE.

It has been clearly demonstrated in this work that the comZONES are a valid design concept that works. New comZONES can be developed and placed into the same structure. Equally, other concepts could be developed which may work just as well for the design and the integration of VMC in the domestic environment.

6.3 The Design of Private and Public Spaces

- How can private and public domestic spaces, in relation to video mediated communication, be designed, considering functional aspects?

Video mediated communication is introduced into the dwelling in different conceptual VMC set-ups. These are designed to establish the digital public spaces, the so called comZONEs, generated in the dwelling during the use of the communication. Also, the function of the comZONES is to delimit the public space from the private space.

Paper 2 introduces the functional and physical design of the different comZONEs. The comZONEs were defined by technical solutions such as display screens and cameras as well as by the use of their architectural design like spatial forms, colours, light, texture, and

fabrics with the aim to support the function. Thus the architecture, in combination with technical solutions, establishes an interface to the digital world.

The video film in paper 3 illustrates the functions of four of the comZONEs presented in paper 2 with an emphasis on the private and public space. The video presentation, albeit only some six minutes, is extremely rich in information. Different observers generally perceive different things. Therefore it is difficult to draw unambiguous conclusions from such a research undertaking. On the other hand, a video of this kind leap-frogs understanding of the barriers and considerably advances discussions on related topics.

In paper 4 the necessity of simple and clear concepts of design with regard to both technology and spatial forms are strongly confirmed. A direct result from the study was that, concerning the workplace, the initially designed semi-public zone – between the public and private zones – was removed in order to make the boundary between the public and private zones more apparent to the users.

A result of this topic is that the traditional private space and the new public space of the comZONES have to be easily recognisable by those who live in the home. The boundaries between the zones have to be made as clear as possible. How this shall be designed is open for creative solutions.

6.4 A Formal Method to Describe the Design

- Can formal methods be applied to describe the design and integration of video mediated communication in the domestic environment?

Architectural designs, before they are constructed, are normally presented through sketches, formal drawings, illustrations and models as well as through verbal and textual descriptions. This methodology has developed over hundreds of years for the building process.

Paper 5 is directly oriented towards the application of a formal method of design description. The Design Pattern Language, a formal

structured method to describe architectural design is introduced, developed by Christopher Alexander in the 1970s.[188] The method is applied to the design ideas for video mediated communication developed in the comHOME flat. Its purpose is to systematically describe the generic design concepts related to private and public digital spaces in connection with VMC. The new patterns are introduced within Alexander's structure and refer to two separate levels according to its definition. On the first level a specific pattern, called "PRIVATE AND PUBLIC DIGITAL SPACES", is designed as a conceptual floor plan layout. This plan distributes private and public digital spaces for video mediated communication over the flat. On the second level, four patterns show the integration of the specific comZONES aiming at solving four specific problems with video mediated communication at home. In this work, the Design Patterns were explored as a method for analysing and solving unique problems encountered with the introduction of information and communication technologies in our homes.

It is shown, in paper 5, that it is possible to use a formal method for this purpose. In this way, a clear result from this part of the study can be shown. It is not asserted, however, that the specific Pattern Language method developed by Alexander is probably neither the best nor the ideal method for describing the design and integration of VMC in the domestic environment. In fact, it is not certain that the application of formal methods at all is the most appropriate way to plan for the introduction of VMC artifacts in homes.

6.5 VMC Supported Domestic Activities

- Which domestic activities can video mediated communication appropriately support?

As mentioned in paper 1, VMC can support and complement a wide range of home based activities like professional work, studies, and leisure activities and also give support to the care of the elderly and otherwise frail persons.

[188] Alexander, et al., 1977.

Paper 2 points out and discusses a number of more specific activities in relation to different concepts for VMC in the home.

In paper 3 – the video film – a number of different in-home activities, previously developed in paper 2, are demonstrated; for example, professional work, preparing a meal, having dinner together with a remote guest and celebrating an event. The support from different VMC solutions is instrumental. People without prior awareness of this kind of application usually recognise and accept the scenes, albeit sometimes with an indulgent smile.

In paper 4, two of the comZONES were applied in a test. A formal process of work was tested at the videoTORSO, and at the workplace informal everyday communication was tested. The given tasks were generally fulfilled without perceptible problems. The tests were limited in scope, however, and it is too early to draw far-reaching conclusions from these few preliminary experiments. Recently further tests have been presented, confirming the early judgements.

The activities that are supposed to gain most by VMC are mainly of two kinds. The first kind pertains to activities requiring a high degree of visual information to address and solve a situation or a problem. Typical applications of this kind are when a doctor can remotely observe a child, a designer can show a physical item to a co-worker from the home, or a personal assistant can guide a disabled person in the process of preparing a meal by him or herself. The second kind of activity is such interpersonal communication that typically is accompanied by emotions expressed in body language. An example is a grandmother that, whilst talking to her son over a video communication, can see her grandchild in his arms waving her hand.

In this chapter some of the answers to the research questions put forward in chapter 3 have been presented. In principle these answers are based on the findings of the five papers forming the central part of this study. In the next chapter a more general discussion of the work as a whole is given. Some comments on the methods applied in the study are added. Also the potential for further research in the field is discussed.

7 CONCLUSIONS AND IDEAS ON DESIGN AND FUTURE RESEARCH

When this project started in 1996 smart homes was an issue primarily seen from a technological and business development point of view. The architectural perspective was poorly addressed, except for some disperse theoretical work. Neither were there any relevant research approaches found about VMC in connection with the domestic context. Later in the 1990s smart homes were successively seen more from the users' point of view. However, it remained that the spatial consequences were hardly noticed or commented upon.

The present work is certainly one of the first research projects dealing with VMC in smart homes from an architectural perspective. During the course of the research work, smart homes as a topic has grown, albeit still in an unfocused way. Current research and development on smart homes is diverse. The social and political interests, especially the functionalistic movement, related in chapters 2 and 3, generated research and development initiatives concerning the use and design of the home. As we are in a similar period of change we might need something comparable today, taking up important issues for domestic life in contemporary society. The subject itself is broad, which is elucidated in this work. A research programme on areas related to VMC and smart homes can very well be justified. Exactly how such research should be organised, its points of departure and its objectives must be open questions for the time being. Some concerted action by public and private bodies addressing important societal needs and potential markets will certainly find an abundance of unexplored fields of knowledge. In this concluding chapter some ideas about such approaches will be touched upon.

In addition to the findings elaborated upon in the preceding chapter, some comments are made on the specific applied research methods associated with the presented work, and also some reflection is made on the work with the comHOME flat. A section called Challenges for the Design of Future Homes is developed and some final thoughts are discussed at the very end of the chapter.

7.1 The Research Methods

The research work consisted mainly of the design of the principal test site, the comHOME flat, the definition of the VMC set-ups, the comZONES, the conducting of the experiments at the site, and theoretical work related to the test undertakings. The research and development activities were carried out in different environments, which has enriched the scope and brought in complementary views on research objectives and methods. As stated earlier, the overall research approach is explorative and design oriented, see chapter 3, with a clear multi-disciplinary point of departure. Several fields of knowledge as well as methods and theories from different scientific disciplines have influenced the work. The concept "Archaeology of the Future" was particularly helpful as it offered a uniting metaphor for the researchers taking part in the development of the test site as well as for those who proceeded by using the site for further experiments.

For the stated problems the multi-disciplinary and explorative way of working has been useful. It permitted large steps to be taken forward and allowed totally new ideas and concepts to be explored. On the other hand, this may imply that the resulting findings, at least to some extent, are dependent on the research environment, its governing paradigms, and in the end on the researchers themselves.

Research which includes the design of the object for the studies – it may be called design-oriented research – tends to become more attractive and frequent, not only within the creative disciplines but within technological research in general. Such research implies the creation of some artifact or a work in general, a description of what has been achieved and how it was done, accompanied by a subsequent reflection on the undertaking as a whole and its implications. This research paradigm is still searching for its structure – at least a proviso structure – in order to carry out more effectively research tasks with academic aspirations. Interesting questions to develop, related to such research, concern, on the one hand, how to handle these design and development activities, and on the other, how the particular (i.e. the study of one-of-a-kind specifically designed object) can be generalised into findings with larger compass. The integration of traditional research methodologies into design-oriented research is another matter of principle.

7.2 Some Reflection upon comHOME

As mentioned earlier, comHOME is the particular design project used in most tests and evaluations reported upon in this study. The strong involvement of the Author in the whole design and building process was extremely valuable. Not only for the possibility to implement all the design ideas, but also for a better understanding of the complexity of the system integration of all the technology. The involvement in the whole design and building process was also most valuable for the proper understanding of limits, possibilities, and functionalities of the installed equipment, systems and its integration.

The design and the establishment of the comHOME flat proceeded well. From the start, the flat was fitted with advanced systems and equipment for home automation, multimedia and telecommunication. The project had superb support, primarily provided by the S-lab at Telia, which allowed almost unlimited access to required technology and necessary expertise. Several ideas planned to be developed and integrated in comHOME at later stages were never realised. A tracking and positioning system recognising the precise location of a user in the flat and integrated with the VMC-set ups, commenced but was not accomplished. Neither was full integration of the different systems for home automation, multimedia and telecommunication achieved. The comZONEs never fully functioned according to the initial design ideas, especially with regard to the capturing and distribution of audio and video.[189] For the research projects carried out by the Author the deficiencies of the technology never became a marked problem. The intended fully working system could be well expressed with the video film, and the incomplete functionality could temporally be simulated in practical tests with test persons.

7.3 Challenges for the Design of Future Homes

Currently there are not many multi-family homes under construction in Sweden. Any major change of this situation is not envisaged. Hence, both new buildings and the large stock of existing buildings

[189] The only place for VMC that actually worked more on a regular basis was the mediaSPACE, not the way it was supposed to work according to the original design ideas presented in the papers, but with a generic software for video-conferencing.

have to be taken into account if the smart homes development will advance in the foreseeable future. Different applications, for example, prolonged living of older people in their own homes, which are supposed to involve smart installations, are typically oriented towards existing buildings.

The main architectural issue for this work concerns the use and interpretation of space related to VMC in smart homes. Public digital space is demonstrated to be a new issue of consideration for architects designing smart homes with VMC solutions. The spatial layout of the room influences the location of screens, cameras and microphones. Doorways and floor plan layouts have to be designed so as to prevent non-participants in the communication interrupting by passing by. Windows should provide natural light, improving the quality of the screen images both in the home and what is perceived remotely.

Another major concern should be the increasing number of potential conflicts in the home as several activities supported by ICT will be performed within the same space and at the same time. The technology, especially in combination with open floor plans, may induce conflicts between users using different communicative artifacts. Not only is the space open, but flickering images and sound occupy it as well. The functionality may be governed rather by the typology than the size of the flat.[190] This is an obvious field for further research.

A specific issue is the question of privacy for the people living in homes with VMC systems. Having a number of cameras in the house will most probably make many people feel uncomfortable or worried about being seen and heard even if they know that the systems are deactivated. To diminish or eliminate this fear, user interfaces have to be designed so that the mode – turned on or turned off – is absolutely unambiguous to the average user. A physical indication, proposed at the design of the comTABLE, see paper 4, comprising the putting down of the screen and the camera into the table, could be one kind of solution. Another possibility is a technically activated signal. For the comHOME flat, an illustration of this could be the turning off of the

[190] Junestrand & Keijer, 2001.

video communication being triggered by the user leaving the public space at the workPLACE.

7.4 Some Final Thoughts

This work raises an almost unlimited number of possible issues and questions about the studied subject and its relationship to a multitude of related phenomena currently of major concern in our society. This thesis, however, specifically addresses two particular areas, video mediated communication (VMC) and the architectural design and significantly, the relationship between the two. VMC in smart homes offers a large number of potential functionalities and services that could be implemented both at test sites and in real life. A core problem remains the need to understand even the most basic demands on potential functionalities and services.

The care of disabled and elderly people is an imminent problem of profound societal interest in many countries. Care is supposed to take place in the carers homes, much more in the future than presently. Would VMC and smart homes technology contribute to solutions which could enhance people's well-being, preserve integrity and dignity, and ease the relatives' anxiety and, at the same time, contribute to diminished costs for care? The development in the field is hampered by profound lack of sufficient knowledge about what functions people really want and how much they – or the responsible financing bodies – would like pay for them. The house-owners' role for such a development is crucial and has to be addressed as a specific problem. More and wider investigations need to be performed, including full-scale experiments, aimed at specifying functions and technologies for different user groups.

However, the home is not a simple place to describe. In a home the activities and processes are not always decided on by reason, efficiency or effectiveness. Habits and traditions as well as ethical and moral values have to be taken into account. Emotions and satisfaction of desires rather than usefulness may be decisive for the general acceptance of new artifacts to be introduced into our homes. If these matters are well understood by future designers of smart homes, we shall see an increasing acceptance of the new artifacts explored in this study.

Finally, a concluding thought. The quotation from Gabrielsson Åman in the end of section 3.2, which referred to architecture as the truly physical, as the sole relief in our bizarre time, may after all in due time be replaced by an extended architectural understanding of space, encompassing also digital space and contributing to the ease of living a good life in our homes.

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Paper 1

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The Dwelling as a Place for Work

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Abstract. This paper will discuss the future use of the dwelling as a place for cooperative work. It is our opinion that the development of the communication technologies and the architectural design has to be treated in parallel when we discuss new forms of living and work habits. Our analysis is built on a theoretical framework that is reflected through earlier experiences in IT technology in domestic environments as well as field studies of computer-mediated communication. By taking into consideration both architectural and communication technology issues we have developed a framework of how these two areas could fruitfully meet in new design concepts. Some of these concepts are now being used in on-going projects where new forms of communication in domestic environments are studied.

Keywords. architecture, computer supported cooperative work (CSCW), video-communication, telework, dwelling, ambient media

1 Introduction

The purpose of this paper is to describe some aspects on how a future dwelling architecture could be developed and how the communication technologies could be integrated to support cooperative work activities in a domestic environment. The analysis is built on a theoretical backbone reflected through experiences in CSCW (Tollmar *et al.*, 1996, 1997), as well as field studies of IT in domestic environments (Hunhammar *et al.*, 1996). A wider context will be presented by analysing the historical development as well as some trends and scenarios for the future.

The dwelling is meant primarily to support the activity "to live". So, when the way of living is changing the design of the dwelling also changes. Compare, for example, the radical difference between a dwelling of the agricultural society of the 17th century and an industrial worker's home in 1960's. We are now experiencing a major change in our way of living in the transition from an industrial society to an information society. Our hypothesis is, therefore, that the dwelling of the information society has to be designed in a radically new way, than the dwelling of the industrial society.

Our key argument is that we will spend more and more time in our homes, where we will also accomplish a wider range of activities, including professional work. The

reasons for increased work, and cooperative work as well, in our homes are - despite the prerequisites of available IT tools - among others (Forsebäck, 1995; Graham and Marvin, 1996):

- New social trends and values in a diversified individual perspective where the limits between the private, e.g. the family life, and the public, e.g. work, are loosening up.
- Changing organisational and economical structure within companies and organisations.
- New attitudes from a political view, both national and international.

The widened range of activities in the domestic life and the technology push will lead to an extended need for communication facilities. These will diversify into a set of communication units for different kinds of use. The motivation for acquiring some technologies in domestic environments might even be derived from the dual purpose of fulfilling both social and professional needs.

One way of understanding different kinds of communication systems is to utilize architectural metaphors in our interpretation of a system. To date, it seems that the imitation of architectural or urban spaces has been the dominant strategy for most of the multi-media telepresence systems (Mitchell, 1995). All of these electronic systems are based on a rationale of projecting architectural props into an electronic space, i.e. a room or a table. We would like to argue that such metaphors should be pushed even further.

The major goal with this paper is to work out a framework where we can play around with concepts in modern architecture and communication technologies. This paper focuses on architectural and IT-communicative perspectives of dwellings in Sweden and primarily for a growing group of people working in the information sector. Of the different components that computer supported cooperative work consists of we will focus on the live video and audio communication. The paper, in current scope, will it not include any deeper discussion about e.g. social, economical or political aspects. However, all are additional important facts of the implications of the new IT technologies for the society of the future.

2 Scenarios of the Dwelling, Future Life and Work Style

Two scenarios are developed showing different situations where live video communication forms a part of work and spare time activities. It is our hope that the scenarios might work as an introduction to the complex situation of new needs and possibilities involved in the field of new communication technologies and the architectural design of the dwelling.

The scenarios take place in a eleven stories residential building in a Stockholm suburb. People living in the house well represent the new dominating group working in the service and information sector. The year is 2010...

"When the kids comes home"

It's 4.15 p.m. a Thursday in May and David, a married father of two twin daughters is at home working, just as most days of the week. Now he sits in a semi-transparent glass-cube, which is a sort of transit from the staircase to the apartment. He's having a business videoconference.
- Okay David, your comments on the design were great, says Roberto on the big screen. I will do the changes and call you back when it's done. Anyway how are you wife and kids?
- Great, thank you Roberto! Wait, I can see Maria and Sara coming here in the staircase. They are in the hallway now; maybe you can see them coming. They have been to school this afternoon.
- Hi Maria and Sara, welcome home, says David to his daughters. - Say hello to Roberto, a friend of dad who lives in Brasilia. Maria take a step forward and waves her hand to the video screen. And says: - Hello Roberto, I'm Maria. - Hi Maria, answers Roberto, I like your backpack! - Oh really, says Maria, It's my portable computer, I need it for school.
- Alright Roberto, see you soon and send my regards to your family, finishes David.
The screen automatically shuts down and David pushes the movable wall and places it in front of the glass panel leading to the staircase. By doing so he converts the hall into a more private space than the public working space he needed during the day. At the same time he takes the chair he was sitting in and moves it close to the panorama window. Then he turns the chair upside down and suddenly it becomes a comfortable rocking chair for reading a book later at night…

"Talking to grand-ma"

It is evening, 6.30 p.m. The father and the youngest son are watching the children TV together. A "virtual agent" asks if they are willing to take an incoming call from the grand-ma. Steve, the father, replies:
- Yes, of course, you don't have to ask for that, put her through … Hi mom, how are you doing?
- I'm fine, how are you John? I'm sorry to interrupt you in the middle of your TV show.
- That's ok, what's on your mind?
- Well its John's birthday next week so I thought that I should ask if he has any special wish.
John replies immediately: - Yes I would like some new pieces to my Lego robot.
- Grand-Ma ; That sounds expensive! But we will see. Could I talk just to you Steve, and Maria (the mother) so John can continue to watch his show?
- Yes of course, says Steve, I think Maria is still in the car, so let us meet in the kitchen in a minute.
- Okay, I wait for you there, replies Grand-Ma.
Steve re-routes the call to the kitchen with the help from his "virtual agent", and ask it to locate Maria…

3 Architectural Concepts

The most important concepts in the development of the architecture of the dwelling are primarily: time and space and the concept to live. The concept of time and space are important depending on where, when and how one actually does things - in this

case to 'live in your home'. The concept live in an architectural perspective is a condition for the being and the space that can not be separated (Norberg-Schultz, 1971).

3.1 The dwelling

Historically the activities in the agricultural society where often integrated both in time and in space. Work and idle time where not separate concepts and the whole household participated in the daily work. The majority of activities took place inside or around the buildings. The dwelling was the physical form of the way to survive, and the form was decided by practical and ecological conditions.

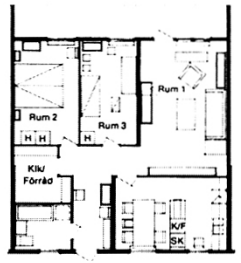


Fig.1. Plan of a Swedish farm with spaces for the majority of the household's activities spread out in different buildings united in one physical form.

Fig. 2. Plan of a typical apartment of the 70s, showing an obvious division of some of our different functional activities into spaces.

The industrial revolution lead to the division of 'work' and 'live' for the majority of the population and the dwelling turned into a "machine to live in". The dwelling was now designed for: homework, personal needs, spare time activities and studies for the young generation. The professional work was no longer a part of the dwelling and should be done in the fabrics or at the offices. The activities where separated in time and space with the dwelling at one place, the workplace at a second and the central functions at a third, all tied together through private or public transportation.

The dwelling of the information society will again, probably, represent a wider spectrum of activities integrated in time and space. What will happen is that we, to a much greater extent than today, will work from home, shop from home and take care of the elder population in their homes with support from different IT solutions.

3.2 The concept of time

"Einstein's theory of relativity introduces into physics a notion of time that is intrinsically flexible. Although it did not quite restore

> the ancient mystical ideas of time as essentially personal and subjective, it did tie the experience of time firmly to the individual observer. No longer could one talk of the time - only my time and your time, depending on how we are moving. To use the catch phrase: time is relative."
> *(Davies 1995)*

Time might apparently be a very simple concept, but it is actually extremely complex and has many ways of interpretation. Here we will, in the first place, focus on how we relate to time. We will also discuss how time is perceived. Worthwhile to notice is that the way we in general relate to time is well behind the more scientific or intellectual understanding of the concept.

In the old agricultural society the relationship to time can be described as circular. The reason for this comes from two directions. One comes from the very nature itself and one origin from the philosophical ideas of Plato. With "from the nature itself" is understood the cyclical character of the nature - the repeating character of the day, the week and the year (Davies, 1995). Practically, this relation to time resulted in an adaptation to the nature's outer factors. Philosophically, the circular understanding of time was the way Plato described the time from a more scientific point of view. This model has left deep marks in the western culture.

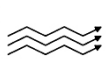
RELATIONS TO TIME			
	"CIRCULAR"	"LINEAR"	"PLURALISTIC-SUBJECTIVE"
GRAFICAL ILLUSTRATION OF THE RELATION TO TIME			
SCIENTIFIC REPRESAT	PLATO	NEWTON	BOLTZMAN
HISTORICAL EROACH	"AGRICULTURAL SOCIETY"	"INDUSTRIAL SOCIETY"	"INFORMATION SOCIETY"

Fig. 3. Graphical illustration of different relations to time in different historical epochs with an indication to identify who originally represented this point of view - in a scientific way

The industrial society's demand of an exact and chronological order in production and distribution changed the concept of time from circular to linear (Davies, 1995). There had been an acceptance of an order of time in earlier cultures. But that time could be something precise and objective became possible with the modern science (Davies, 1995). Most things such as production of goods and services where measured in time and time studies where done even of activities in the dwelling, e.g., house-wives work in the kitchen.

Time in the information society will rather be perceived as *pluralistic* and *subjective*. Time will be treated as related to: rhythm, length, speed and quality (Mead & Pacione, 1996; Philips, 1996). More concrete this could mean that we might feel that the "time is running by" or that something "goes on for ever". In a more global world of information, this new conception of time, means that it's more important what we produce and not when and where we do it. This results in more flexible and individual forms of work and everyday life.

We will be connected and prepared to communicate any second of the day. This will obviously cause problem in domestic environments, in particularly how to handle quality in time - both focus as individuals and as family members. Should, e.g., *all* phones-calls be re-directed towards the answering machine during the family dinner?

3.3 The concept of space

> "Architecture is the thoughtful making of spaces. The continual renewal of architecture comes from changing concepts of space."
> *Louis I. Kahn*

The concept of space refers to what Norberg-Schultz (1971) describe as: "architectural space may be understood as a concretization of environmental schemata or images, which form a necessary part of man's general orientation or 'being in the world' ". Man has not always only existed and acted in space, but also created spaces as an expression of their understanding of the world. The architectural space and man's way to relate to and act in it have changed over time.

In the industrial society the concept of space became scientifically rational and in general a spatial result of the analysed function which would take place within it. The dwellings got sleeping rooms, bathrooms and living rooms. The need, will and belief in structuring and classifying even the spaces became important. The American architect Louis Sullivan founded the expression "form follows function", during the late 19th century.

The concept of space in the information society is becoming more complex and can be understood as two parallel spaces: *the electronic* and *the physical*. The electronic space consists of one *representative* space such as virtual reality and another *abstract* space which refers to an non-hierarchical one with free associations and parallel places (Mead & Pacione, 1996). The physical space, on the other hand, is the single world where we actually are with our bodies. Hence, the electronic space is global while the physical space becomes more and more local when we spend more of our lives in and around our dwellings.

3.4 Private and public

In the agricultural society where the limits between what we today define as private and public spaces not yet defined. People lived and worked inside the farms main building, outside close to the buildings, or on the fields as a group, i.e., many people slept in the same rooms and beds and the "toilets" consisted of many holes in a row (Rybczynski, 1988).

The concept of public and private has during the industrial age developed and become something really important. The private became absolutely private and public became totally public. The earlier public characters in, e.g., traditional farmers house disappeared in the modern planning. The limits between public and private became sharp; compare for example the public character of a staircase and the very privacy of the apartments hall in a typical residential building of the later decades. Norberg-Schultz (1971) describe this phenomenon as "We have already mentioned variation in the public and the private aspects of the dwelling, and hinted at the fact that modern man to a large extent has lost the level of nature".

The way to live in our homes in the information society is becoming more complex and with an increasing integration between work, shopping and domestic activities, the limits of private and public will open up (Graham and Marvin, 1996). We will also experience new ways of communicating. The technology will, e.g., permit us to break limitations in physical proximity by real-time video communications. Radically different means of connecting places is that everyone can "be their own television broadcaster" and make, i.e., a family home page that opens up the physical family household environment to become more public.

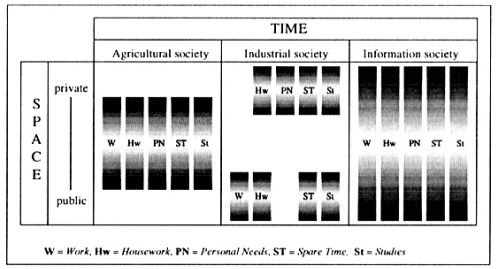


Fig. 4. A schematic image over how activities in our everyday-life are located in a private-public aspect over the epochs.

4 Basic Communication

> "Many of the significant issues in differentiation arise from the physical environments from which we enter "virtual" spaces; the existencies of particular, local situations lead to variations in virtual behaviour. The homogeneity of distributed communities is often illusory."
> *(Dourish, 1997)*

As the time spent in domestic environment will increase and the activities will undergo changes, the need for new communication facilities will grow. These will diversify into a set of communication units for different kinds of use. We will now discuss some of the implications new communication technique might incur for the domestic environment.

Given the variety of communication in domestic environments one must emphases on the needed flexibility. Another key factor is to stress the importance of social interaction among members facilitated by work or by common ties. We may take this a step further and note that in designing domestic communication facilities, the following core attributes might be crucial in creating a sense of accessibility and proximity:

- Finding people and information.
- Creating and sharing social space and workspace.
- Keeping track of events and participating in the governance.
- Use and control of communication media.

Our starting point is the number of prototypes, usability studies and fieldstudies, that have been undertaken on mainly video-communication facilities, e.g. mediaspaces (a virtual space mediated a communication act over distance), within the CSCW (Computer supported cooperative work) community. Previous research on video-communication has revealed many contradictions in our understanding of this communication media. Issues like non-verbal communication and media quality has been heavily debated in the literature (Whittaker, 1995). In the context of this work have privacy concerns turned out to be of special interest. In particular, as some places of the future dwelling will become semi-public places, like the family hallway, a dilemma exists where the private, individual, and public space meets. Paul Dourish has reported (1997) about the continuous efforts to experiment with different solutions to privacy issues in mediaspaces. Durish pointed out the contradiction of the nature of mediaspaces as hybrid physical / virtual environments.

4.1 Architectural interpretation of communication media

One way of understanding different kinds of communication systems is to use physical metaphors in our interpretation of the system. To this day, it seems as if the imitation of architectural and urban spaces has been the dominant strategy for most computer meditated communication systems.

In, e.g., the University of Toronto's video-conference system (Mantei *et al.*, 1991) a part of the interface consists of small thumb-tack windows, with names underneath of people, who are potentially available for a video-conference. If a person is in her office, a small picture her is displayed, if they would rather not be disturbed, a "half-closed door" reveals only part of the face, and if they really do not want to be interrupted, there is a "DO NOT DISTURB" sign. The design principle was to transpose everyday interaction rituals to an electronic world, based on the social meaning of physical artefacts (i.e. half-closed doors). Architectural props, were used as symbols of an individual's desire for engaging in certain kinds of social (electronically mediated) interaction ("I am busy but if it's really important you can interrupt me with a video-conference").

The intended purpose of such features is to allow the transposition of everyday conversational mechanisms into mediated communication. The essence of this point is an emphasis of the emergence of designing the physical space so it has the affordance of being both virtually and physically shared. The work by William Mitchell (1995) gives us some further references. Mitchell makes a parallel between successful new electronic places and how the urban space was designed in the ancient Greek *agora*, "It was the possession of an agora that made a collection of buildings a city". Mitchell lists four major characteristics that make a space *agora* like:

- Accessibility, open.
- Friendliness, non-hostile.
- Freedom of assembly and action, providing high level of freedom in action.
- Public control of use and transformation over time.

Another worthy source is Ray Oldenburg's (1989) analysis of the concept "third places" in his book "The Great Good Place: Cafes, Coffee Shops, Community Centres, Beauty Parlours, General Stores, Bars, Hangouts, and How They Get You Through the Day". Third places are, according to Oldenburg, neither home nor work, but are places where informal public life can take place. Third places around the world share common and essential features, they are levellers - inclusive rather than exclusive and expand social possibilities.

However it's our standpoint that most imitations of architectural and urban space and places that are used in today's development of communication systems are too crude and superficial. We all know that clever architectural design is like a clever interface - intuitive, attractive and transparent in a subtle combination. In a physical space it is all these subtleties that shape or do not shape the communication within a building, office, public bar etc. Designer of today's electronic communication media unfortunately do not push and advocate the architectural metaphors far enough.

4.2 Create and share social and work space

In our latest research project in video-communication, the VideoCafe project (Tollmar *et al.*, 1997), we started from an idea of virtually connected public places in two research labs that were about to initiate an collaborative research program. The idea of providing a public mediaspace was built on the assumption that such a space could act as a facilitator for informal community building. By empowering the individuals to be able to take an active part in the discussion and change future plans and activities.

One of the core activities in the VideoCafe project was to experiment with a couple of different room designs. For that purpose we created both new social places in workplaces as well as new styles of interior design that could foster a community.[1]

- In connection to shared communication devices (see Fig. 5),
- For lobbies (see Fig. 6),

[1] All the places that we here discuss are located within or close to what now is CID (Center for User oriented IT Design) at the Royal Institute of Technology, Stockholm, Sweden. The different interior design solutions for the other research lab at Ericsson MediaLab are discussed elsewhere (Tollmar *et al.*, 1997).

- For shared laboratories (see Fig. 7),
- For public lunchrooms (see Fig. 8,9).

4.2.1 The Corridor

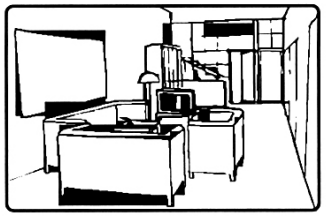


Fig. 5. The VideoCafe concept placed in a corridor.

A corridor was the first place of installation (see Fig. 5). The place was close other communication infrastructure, such as faxes, Xerox machines and mailboxes. It also was close to some of the staff member's offices. In general, it could be described as the place through which everybody had a reason to pass, several times per day.Our basic idea was to enrich this place of encounters with the remote lab's presence, but since it literally affected everyone in the lab in a very direct way, several privacy considerations were undertaken to give the place the affordance of different communication zones. The place was divided into three different zones:

- an inner zone where the user could be both seen and heard,
- the background zone where the user could be seen but not heard,
- a free zone where you are neither heard nor seen to be used, for example, by people passing through whom would like to be left alone.

In practice it turned out to be hard to strictly, but flexibly, control the technology in such way that the different zones were clearly distinguished. If you were engaged in a conversation it was hard to protect that conversation, and the place could actually also exhibit a hostile character due to the problem of shielding a conversation. In addition, we found a problem in the fact that public places tend to be owned by their neighbours. What the corridor place lacked in agora terminology was, despite it is accessibility, obviously some proportion of friendliness.

4.2.2 The Lobby

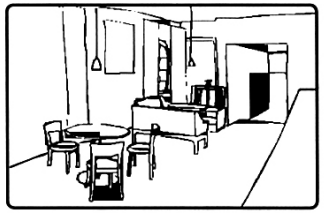


Fig. 6. The VideoCafe concept placed in a lobby.

The second place for our prototype was a lobby. The lobby has a more defined role, and is mostly nomans land. Furthermore, compared to the corridor, it is usually not that heavily trafficked and hence provides a calmer atmosphere for longer conversations (see Fig. 6).

However, in our case this place did not work at all. Comments that were made indicated that this is a place of merely pass through, and very seldom a place where you stop to chat. The frequency of informal encounters dropped noticeably. However, compared to the corridor, this place supported better semi-formal meetings between the labs. Due to its calm nature it became a greater place for extended meetings.

4.2.3 The Lab

Fig. 7. The VideoCafe concept placed in the lab.

Our next step was to find a place, which combined the positive aspects from the lobby with the possibilities to, afforded the frequent encounters that the corridor did. The place selected was the common lab. To handle the more tricky privacy issues in the lab, eye-dropping and audio pollution, we removed one of the zones in this prototype. Hence we limited the available zones to two, the inner zone where you can be both seen and heard, and the free zone where you neither are heard nor seen (see Fig. 7).

It became apparent that people working in the lab sometimes, naturally, turned the volume down not to be disturbed in their work. Since the audio maybe is the most essential medium for peripheral awareness the need to reduce the volume came into direct conflict with the casual interactions idea, e.g. when people notice the rattle of keys when a person at the other site lock her door at the end of the day. The basic lesson of the lab place experiment was that we needed to add extra interaction devices to our design. Dependent on where you were standing in the room, the communication devices need to adjust to that specific situation. E.g. if people only move around in the free-zone the audio level should be adjusted as well as the camera being positioned into a small, closed field of view.

Another way of solving this is to replace the direct audio with some ambient form of a less intrusive nature. However this form of media-transformation is a complex matter where we have only started to define our needs and have so far only a rudimentary set of conceptual design experiments.

4.2.4 The Kitchen

Taking into consideration the reflections above, particularly that too many of the lab members felt that efficiency was negatively effected by the VideoCafe's presence in the lab, we experienced rather soon a consensus of the necessity of try out a new place. The new place we selected was a half-open self-service kitchen in connection to the main entrance to CID (see Fig. 8 and 9).

One of the key problems which we observed during the earlier prototypes was the difference between people sitting down, plausibly engaged in some conversation and

people passing through. To be able to work with this, and related issues, we decided to design and build our own tables and chairs according to our needs. The solution was a raised table in the form of a bar. Our basic idea was two-folded, firstly, we lowered the threshold in the initiation of the conversation and secondly we provided a place for short, spontaneous interactions (see Fig. 8).

A problem in the earlier prototypes was that the space did not clearly suggest how many people it was designed for. One of the outcomes of this was that the distance between the participants always varied towards the camera, the microphones and the screen. The shape of the new table also ensured that most participants had a fixed distance between each other. In addition to the tables' two level boards it become possible to separate the hang-around functions with techniques necessary in this settings, remote control, miles of cables, microphones etc.

Fig. 8. The VideoCafe with a specially designed furniture with the two different tables levels for communication devices and the service-area for the user's coffee, papers and pens

Fig. 9. The VideoCafe concept placed as a café with a piece of specially designed furniture.

4.3 Use and control of communication media

In our findings three kinds of control veers feedback, system, audio and visual have been identified as critical. Most important is that the user must be able to control the volume of the received audio and turn on and off the audio transmission. An active user must also be able to control his / hers visual field at the opposite site, as well as be given a visual feedback of the video-picture that are sent to the opposite site. We have formulated our experience in two categories of guidelines - how to form the audio-room and how to control the field of vision.

Many earlier studies have shown that the audio quality is an important factor (Tang & Isaacs, 1993). In our studies we have been trying to obtain one shared audio-room by using directed audio with CD-quality. Points of interest are in this case to find models for audio visualisation of the shared room to enable equivalent conditions for conversations as in face-to-face conversations in physical room, e.g., back-channels for several simultaneous discussions. This turned out to be a very complicated matter to solve. The basic problem is that every single room audio-acoustic properties differ tremendously from all other rooms, it's like a room's unique fingerprint. No-matter

how the audio is processed there will exist a difference in the character of the speech in the physical rooms compared to the transmitted speech from the remote location. Our work-around solution is to filter the audio with extra-ordinary circumspection. But, like in many other design solutions for the VideoCafe, this will raise a subtle balancing act. The trade-off is to make the speech as good as possible at the expense of reducing the background audio, that is so important for awareness mechanisms.

When people sit in the same room they are able to control their own field of vision by moving their head and body 360 degrees and the participants can immediately see in which direction another person is looking. To be able to achieve some freedom in the field of vision for the remote participants we have experimented with using several video cameras at each site. These cameras can then smoothly provide both overview pictures of the room as well as close-ups. To simplify the interaction with these video cameras a simple IR-control device was developed that controlled both local as well as remote cameras. Nevertheless, in practice we found that contradictory to these features most users instead utilises the space to control distance between participants. For example by placing themselves in the room instead of using the zoom function to zoom in a person they are talking with. This stress even further the question of providing even simpler forms, e.g. a remote control, of interaction devices to control the field of vision. One example in this direction is to use different kinds of motion and presence detectors that could perform camera, as well as audio, adjustments.

4.4 Conclusions from basic communication

IT technology is already referred to as a natural component in the way many of us live. Increasing and changing ways of communication will in itself demand new architectural distribution and design of the dwelling. Implementing this for both professional work and social aspects in the context of the dwelling will require more from the technology. With transparent interfaces, intermixed with special devices, it will be possible to focus upon communication instead of technology. Experiences from the use of mediaspaces, that so far primarily have been developed for office buildings, will raise new design-criteria's that seem to be interesting for the dwelling:

- The technology must afford a large degree of flexibility connected to the use of space in the dwelling. It must be possible to transfer a call to another place if the discussion shifts and gets too intrusive for the environment. The space should also afford people to connect to a discussion.
- If a permanent link is connected to places apart there exists big needs of additional levels of communication, sometimes the mediaspace is too noisy and intrusive and in other occasions it is too passive and does not afford that kind of casual communication it is intended for.
- The need for a comfortable and easy interface not distracting the communication act but allowing on-the-fly adjustments of the technology could never be over-exaggerated.
- Problems concerning interior design issues are colour and lightning. Firstly the interior colours need to be colours that can be transmitted with video without distortion. Secondly, does lightning have to be a compromise between the studio lightning and the lightning of a living room.
- Of great importance is also how to create a shared context in the interior that provides an "us" feeling between two rooms.

5 Discussion

The dwelling in the 21st century might not at all mean the same thing as in the 1990's. In the 21st century people will have a greater part of their everyday activities in and around the dwelling. This includes both traditional home-related activities and professional work. The border between homework and professional work will loosen up. Fewer people will have a permanent employment and more will work in temporary projects or run their own business, with the home as their stable and fixed point. A greater number of these activities, i.e. professional work, shopping on Internet, care of elder people and childen, and video-telephony, will also be supported by different kinds of communication technologies. The dwelling will in this context function as the physical base of one's existence.

5.1 New use of communication media

From our studies of video-communication we have found two interesting strands of further development that might be of special interest for the appliance of mediaspaces technologies in domestic environments. Firstly, there exist a big need of different levels of communication. Sometimes the mediaspace is to noisy and intrusive and on other occasions the mediaspace is too passive and cannot allow the kind of casual communication that it is intended for. Different forms of media transformations seem here to be a promising direction for further development. Secondly, even a simple function like adjusting the camera with a remote control could easily create breakdowns in the discussion. An alternative kind of interface that utilise the position and the gestures of the body in the room could be a comfortable and easy alternative interface.

It's our standpoint that concers regarding privacy, a major source to problems in office environments, will only be more important to handle properly if we want to move this kind of communication techniques into domestic environments. Our new direction is to examine some alternative solutions where some media undertake some transformation into new forms, media forms that maybe is not direct and intrusive. It might be wanted to, in some domestic environments, make it possible to hear, rather than see, where other things or people are and what they do. Both due to privacy concerns but also to practical concerns since it is not possible to look around every corner in a domestic environment. Like cord-less phones, we would like to enable users to freely move around and let other more practical factors decide where the communication act takes place.

A mix of the above questions yields a generic issue; *could the room adjust itself to different levels of communication?* Depending on people's position and activity, e.g. use of other services. We are especially interested in investigating different kinds of mechanisms that, in a semiautomatic way, based on preferences and physical controls, help the user to adjust to a suitable level of communication. Today, we are working with motion and image detectors to adjust audio and visual fields in our system. A general guideline is to build the interface as transparently as possible, the ideal is that you will be able to use your body in the room as the main interaction device.

5.2 The architectural and communicative expression

Although the later part of this paper focuses on communicative aspects in the use and design of the dwelling, we will here continue the architectural discussion from the first part of the paper. Lately some architects who have intended to approach IT and communication aspects in the dwelling have done this from a view that the use and meaning of the dwelling is something permanent, and not something that develops with a changing of the way of life. Therefore we discuss some general aspects of a future architecture.

Architecture has always expressed some of the fundamental ideas of the time in which it was created. The information age will be unhierarhical, subjective and flexible among other characteristics and so will it is architecture. Rather than 'tearing down and building new' as in the industrial age, reconstruction, addition and extension will be the dominating way in the construction of the information society. The huge number of existing dwellings will experience a great change to adapt to new and changing needs in the information society. New building elements and techniques will probably be mixed with traditional ways of building. The architectural expression will therefore be a mixture of old and new ideals, forms and materials. Sensors will be built into materials, building components, machines and furniture are meant to collect and transmit information. This will add to traditional ideas about architectural elements and expressions, a new dimension and meaning.

Some architectural design ideas and concepts have been developed from the above discussion. These are here presented in a wider sense:

- There will be an extended number of activities taking place in the homes and these will vary during the day and the week. The average time spent at home will also increase, which means that with maintenance of today's use of space will be a needed to adapt the dwelling according to the activities taking place at the moment. A solution might be *flexible and moveable walls and wall-systems* that could provide spaces adequate for the changing activities.
- Apartments from the industrial ages are generally very closed towards any public space and of a strict private character. There are reasons to expect an increasing need to physically *open up* the apartments towards the public staircase, e.g. with glassed walls or new physical forms.
- Changing and more extended use of the buildings *common spaces* for activities such as meetings, delivery of products and tele-work in favour of e.g. laundry and storage will take place. These semi-public places will in this way temporarily become more private. The borders between the public and private will in this sense be more flexible and diffuse.
- The lack of space and the different characters of the varying activities will also demand a wider use of the furniture in domestic environments. Today a bed, table or chair normally is designed only for one single function. But there will be an increasing demand for multifunctional furniture, adaptable - in colour, size, form and other characteristics - to different activities and situations.

Another overall aspect is that these technologies, building components and furniture not only have to be able to adapt to different situations but also to personal needs and habits.

5.3 Future work

An architectural design solution for distribution of video-communication that we are working on is to divide spaces in the dwelling into *different zones* were each zone has an intuitive clear communication mode, as we above argued. The zones may vary over the time and so might the spaces' forms and functions. From this, a more specific architectural and communicative design concept might be developed mutually. A design which is a combination of technology solutions and physically building components.

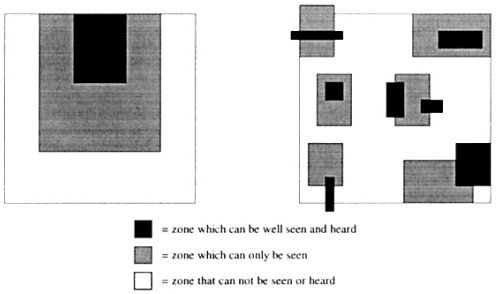


Fig. 10. Graphical illustrations of conceptual communication designs.

To the left: Traditional hierarchical design concept for dwellings with one zone placed at a strategic point such as the hallway.

To the right: Alternative "network-floorplan" - developed by the authors - with flexible zones distributed over the apartment.

From our experience it is also clear that this kind of places would strongly benefit from more subtle communication qualities. Qualities, which may not be found in improved video or audio sampling frequency, but qualities that might significantly enrich the experience of remote places through communication technology. We have,

thus, in on-going projects started to explore new spatial and artifactual tools to address other experiences as a complement to the functional media provided by audio and video. The origin of these tools comes from a context of everyday life. The goal is to replace the ambient communication that is obviously lost between remote places but might be replaced by artificial spaces. To illustrate this further we finnish this paper here with some brief examples; imagine a connection between a pair of chairs, if one of them is used the other one will also be heated to indicate (tele)presence, a lamp could be connected to a remote piezo sensors or stretch sensors that toggled on/off depending on remote presence, or that connected places share temperature, air humidity and lightness. Our working hypothesis is that restrictions, for example for privacy concerns - which are of particularly interest for domestic environments, in direct media, could be replaced by incorporating this kind of ambient media.

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Paper 2

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Video Mediated Communication for Domestic Environments — Architectural and Technological Design

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Abstract. This paper presents different solutions for the integration of Video Mediated Communication (VMC) into the home environment considering primarily architectural and technical aspects. The context is entitled comHOME, a concept dwelling of the future designed and built as a full-scale model in collaboration with a telecom operator. The principal problem investigated is the various aspects of private and public zones when using VMC in a home environment. The solution concerns the integration of different comZONES (communicative zones for VMC), where the resident can be seen and heard at different levels varying in time and space. The comZONES presented include, for example, a "videoTORSO" - a large vertically mounted flat screen for informal everyday communication and a "mediaSPACE" - a set-up consisting of a wall of screens permitting shared activities in both time and space. The comZONES are mainly described from an architectural (form and function) as well as technological (hardware and software) perspective.

Keywords. architecture, communication, comZONE, design, dwelling, home, ICT, intelligent building, media space, smart home, video mediated communication, VMC

1 Background

This paper presents a piece of work based on the idea of a changing society where work and other activities at home become more closely integrated in both time and space (Junestrand & Tollmar, 1998). The core argument is that information and communication technologies (ICT) are a prerequisite for the transformation process from a society focused on industrial production to a society dominated by information processing and based on communication (Dahlbom 1997). Based on a theoretical framework for how our living could change due to new social movements and new use of the domestic environment, we have designed a concept apartment entitled comHOME, demonstrating a set of design solutions for the integration of VMC into a dwelling. In this way the home becomes, in some aspects, a public place accessible

through VMC, while still retaining its private nature for several traditional everyday activities. ICT, directly or indirectly, will free us from a large part of the mechanical work we have been used to for a long period of time. Future work activities will consist even more of talking and interacting with other people (Dahlbom 1997). This and other novel ways of working will be possible from almost any location and will be, to an increasingly extent, supported by ICT. Telework from the home, supported by information technologies, is one of the new ways of working predicted to increase in the near future (Bangemann 1994).

It is without doubt an important consideration that the way to live in our homes in the information society is becoming more complex with increasing integration in both time and space between work, shopping and traditional domestic activities. The actual time we spend in our homes is also on the increase. For many of these activities, ICT can support the process despite a separation in space and time. However, since several of the possible ICT supported activities have a public, or semi-public, character, the limits of private and public in the spatial organization of our environment will have to be opened up (Graham & Marvin 1996). The earlier public character of the traditional farmer's house disappeared in modern planning practices. The dual concept of public and private has developed and become something clearly important during the industrial age. The border between the public and the private sharpened up. Compare, for example, the public character of a staircase in an apartment building and the privacy of the apartment hall in a typical residential building of later decades. However now, in the infancy of the information society, it appears that the creation of public spaces in the private dwelling must be considered once again (Junestrand & Tollmar 1998).

2 Video-mediated communication in domestic environments

The development of information technologies is very rapid and several trends and tendencies indicate that VMC will become an important part of communication - in our homes as well as our offices (Kraut and Fish 1997). Communication can, in this context, support and complement a wide range of home based activities such as professional work, studies, care of the elderly and leisure activities. Our particular focus is on the integration of architectural and technical designs. Dwellings all over the world are generally not very well suited for VMC due to e.g. unsatisfactory acoustics, light conditions, technical installations, floor-plan layout and spatial design. On the other hand regular VMC solutions used in traditional professional work environments seem to be unsuited to the home without profound redesign. In spite of the great difficulties experienced in establishing a market for video-conferencing in the professional field, we still believe that VMC is a future technology for domestic environments. This is mainly based on the fact that VMC primarily supports social and emotional aspects of communication (Whittaker 1995) and this is the primary requirement for a VMC system in a home environment. It should also be observed that all currently available VMC solutions so far lack significant qualities such as the capacity to transport information concerning gaze awareness, smell, taste and touch

among many physical cues that we use. This is an extremely interesting area, but one for which it is no place in this paper or our research at the moment.

3 Theories and related work

The complex design of the VMC solutions presented in this paper have been created by a multi-disciplinary group and span over a number of academic fields, each field with a number of theories and interesting works as possible references. Here, we will limit ourselves to presenting the theories and related work that we have found to be most important, inspiring and encouraging.

3.1 Design theory

The theoretical framework of the project presented in this paper is based on the ideas of the sciences of the artificial, introduced by Herbert Simon (1969) and further developed by Bo Dahlbom (1997). Dahlbom writes: "When we realize that the world we live in is an artificial world, a world of human creation, made up of artefacts of all kinds, becoming even more complex and intertwined, our attention will shift from studying nature to contributing to the design of artefacts." In this future science we become, as designers, a part of the design. Our intention is to investigate what is possible in the design and thereafter structure, analyze and share that information.

3.2 Architectural design

Considering architectural design issues in home environments, the work has a methodological relationship to the explorative and creative development of the functional period of international architecture. This primarily refers to the development of new conceptual and practical ideas for the dwelling that took place at the beginning of this century. A period when the house was referred to as "a machine for living in" (Le Corbusier 1923) instead of being a more traditional central place in peoples' lives. There is also direct reference to the more formal aspects of architectural design as far as cognitive and psychological aspects are concerned (i.e. Hall 1966 and Weber 1995).

Architectural projects and research related to the use of IT in the home environment, intelligent buildings or smart homes appear to be more focused on the technology than on the architectural design. One exception is the work done by Olindo Caso (Caso & Tacken 1993) that concerns the analysis and classification of different IT supported activities which can be carried out in the home environment. These strictly theoretical studies aim at presenting a conceptual organization and allocation of IT supported activities in time and space within the home.

3.3 Computer Supported Cooperative Work (CSCW)

Within the area of CSCW research, the importance of a medium that could support informal communication has been debated for a long period of time. The presence/absence of a social context deeply influences how conversations proceed and their results. Kraut (1990) suggests that informal communication is an essential form of human communication. Studies of video-communication have suggested that the main contribution of the video-media is the rich social context (Tang and Isaak 1993). Consequently we believe, as is highly likely, that informal network building will become even more important when part of working time is moved to the home, i.e. that VMC will become one of the major communication media when most of us also work at home.

Naturally, as VMC moves from the office environment to the domestic environment, we could learn many important lessons from CSCW research. In the context of video communication for remote collaboration the major focus has been on whether the video media actually improve conversation or not. Much work in this field has moved along the specifics to find and separate variables that could be used in studies to solve the issue – exactly how valuable is the video media. In some cases researchers have been able to separate variables that move along deterministic paths – but overall has it turned out to be very difficult to generalize these results into a wider context (Whittaker 1995).

In more current research in Mediaspace (Bly 1993) we could see a trend towards non-quantitative studies in an attempt to specify users' perception and awareness of others presences (Dourish 1995). Furthermore, mediaspaces appear to be specially well suited for informal communication (Bly 1993ibid.).

3.4 Social aspects of everyday technology

In our new societies, the worlds of work and play, education and entertainment, industry and the arts and the public and private sectors are no longer strictly separated, neither at home nor at work. Transactions and communications continue around the world at the same pace, whether day or night, whether we are awake or asleep. At home too, we perform many activities at the same time. This has become possible partly due to technology. We cook while watching television, monitor children sleeping in the bedroom while entertaining friends in the living room, and work while listening to music (Venkatesh 1997).

Hughes et. al. (1997) has described the role of technology in the home environment from a mainly sociological viewpoint. The authors mean that the effect of using new technology in home environments is increasing. In their studies they found that "The presence of technology within the home is absorbed so completely into the routine practice of homelife that it becomes yet another way in which those routines can be articulated". Although it cannot be said that technology places non-breakable scripts on daily activities. On the contrary the situated nature of home activities is very strong but they are also constrained by negotiated as well as unspoken rules. So even if re-configurations of rooms often occur, this is carried out within some given boundaries. Hughes et. al. also found that in the cases where technology was a major part in the

re-arrangements, this caused great stress and the technology was perceived as being badly designed and less user friendly.

4 Research questions related to VMC use in homes

The research project carried out here aims at exploring, making proposals and defining further relevant research questions about how VMC solutions should be designed and integrated into the home environment. In the longer run of course, also some general conclusions or results might be drawn from the work. From this standpoint the general research problem could be described as follows:

- How should architecture and technology be designed to support VMC in future domestic environments?

Some central sub-issues are then possible to define from this perspective:

- What processes of future everyday activities in home environments could realistically be supported by VMC?
- How should the speciffic VMC set-ups be designed for the activities it is supposed to support?
- How can the demands of private and public spaces be fulfilled in this context using architectural and technological design?
- What interfaces should be used to facilitate interaction with the system?
- How should the VMC be integrated in other advanced domestic technolgies?

In this paper we are describing what has been done and visions of what is going to be done in the near future in the design of the comZONES in the comHOME apartment. We are trying to provide a general overview of the project and the description below does not aim to provide specific answers to each one of these questions, rather to construct a framework in which to place the themes discussed. The design goals are exemplified as short scenarios when we describe the different VMC set-ups. The key part of the remaining text below discusses how to deal with public and private spaces.

5 comHOME - A vision of an apartment of the future

The comHOME apartment is a dwelling of the future, used both as a laboratory and a as a showroom. The comHOME project covers several aspects of future dwellings. Our primary goal in the comHOME project has been to develop and integrate VMC solutions into a home, although we are also working with making the home smart. The authors bear the primary responsibility for the design of the dwelling while the project has been carried out in cooperation between our research lab, a telecom

operator and a company providing and developing Lon-Works home-automation technology. We would initially like to point out that the comHOME apartment is not a complete dwelling. It lacks a bathroom and the general floor-plan layout is not suitable for a real apartment. It is best described as a full-scale model constructed from a number of scenario-like room set-ups standing each by itself. As an example the activity "Telework" from the home environment cannot be limited only to a specific area as in the design below, but rather, the whole dwelling should be seen as a potential place for work (Junestrand & Leal 1998). Neither is it intended that anybody should live in this apartment for any extended period of time.

5.1 Architectural design concept

The spatial design of the dwelling is based on the idea of creating different comZONES to support the demands of both private and public digital spaces within the home environment. In an inner zone, a person can be both seen and heard through VMC equipment. In the middle zone the individual can be seen but not heard. In the outer zone the resident can neither been seen or heard. In this way the inner zone is a public zone, the middle zone is a semi-public zone and the outer zone is a private zone. (Junestrand & Tollmar 1998). The zones may vary in time and space. These zones indicate places that Mitchell describes as "places where you can hear and be heard, or see (on a display) without completely relinquishing the privacy and controllability of the home" (Mitchell 1995).

The principal architectural issue was the establishment of the mental and physical boundaries between the public and the private in the VMC supported communication zones, i.e. to uphold the absolute demand of being secure from being seen or heard when so desired. It can be assumed that locating activities in a way that a good balance is attained with other everyday activities, as well as for the arrangements for general technical installations, will also be important. The design also takes into consideration both the inside-out and the outside-in perspectives. Meaning that it is of interest how the outer world is perceived through VMC from within the home as well as how the dwelling is perceived from places outside the dwelling supported by VMC.

The different comZONES are expressed by technical solutions such as screens and cameras but also by the use of architecture - spatial forms, colors, light, materials. The architectural space can then, in combination with ICT solutions, form an interface to the digital world. Figure 1 shows a drawing of the conceptual floor plan to be compared to the more traditional floor plan sketch in Figure 2. Both these plans have been used to communicate the basic conceptual idea during the design process.

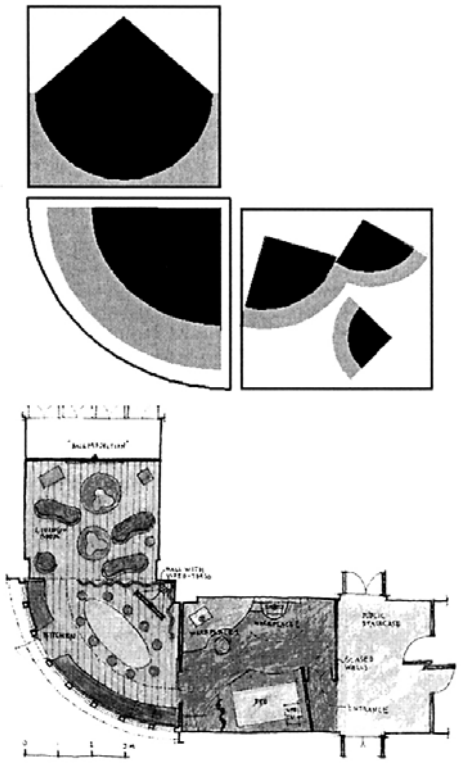

Figure 1. Conceptual design of the floor-plan indicating the comZONES. In the inner black zone the individual can be both seen and heard by the VMC equipment. In outer gray zone the resident might only be seen but not heard. In the sorrounding white zone the person can neither be seen or heard. These zones can vary in time and space.

Figure 2. Floor plan sketch of the dwelling. The entrance is at the lower right. The middle room at the bottom is a combined telework and sleeping room. To the lower left is a kitchen, and to the upper left is a living room.

5.2 Technical design concepts

The technical challenge in deploying VMC in comHOME uncovers multiple layers of complexity. The major difference to be considered is that a home is a radically different place to the more controlled office environment, e.g. poor lighting and audio conditions should be considered as normative rather than rare exceptions.

The technical design of the video and audio space in comHOME is based on several short-range cameras and microphones being mapped and routed through a common media switch. This media switch could be seen as the heart of all incoming and outgoing media streams. The control of the media switch is carried out either via a remote control or a GUI on a terminal, or automatically by the central logic of the smart home. Furthermore, automatic pre-settings could be activated by the central logic of the smart home based on sensor data directed to the media-switch. The video and audio space is hence also closely linked to the design and automation of comHOME as a smart-home. In other words an incoming video call might cause a dimming of the lights or activate the mute command on the radio.

The creation of the different comZONES into the rooms of comHOME is a major technical undertaking. Early works have proposed the use of physical metaphors for control of the video and audio space in VMC systems. One approach, suggested by Kawai (1996), used a GUI with a floor plan to control the field of view of the cameras. Most of these methods suggest using an explicit and direct control of the cameras. In our case, the variation of the zones in space will mainly be controlled by a spatial recognition system that links the physical position with the identity of the person/people in the rooms.

By control of focus depth and field of view combined with the placement of cameras in the rooms we could, using a simple model, fairly well adjust the video-space in the different zones. The control of the audio space is actually more complex. Our primary solution is to mix wide range microphones, such as PZM microphones, with directed microphones. Unfortunately the fairly precise video-space is not matched by equally well-defined boundaries in the audio space. We are aware that array microphones and spatial directed loudspeakers might solve part of this puzzle, but these technologies have not yet become available to us. Similarly prototypes of realtime image manipulation that could, e.g. extract actions or allow people in the background be removed from the videostream do not yet exist.

6 The comZONES in comHOME

The *comHOME* dwelling has three rooms: a living room, a kitchen and a combined telework and sleeping room. In our attempt to explore the usability of the comZONES concepts we have designed a set of six places and scenarios for which we are attempting to describe different design solutions.

A **videoTORSO** for informal everyday communication while standing and talking is placed in the kitchen. This VMC system explores the possibility of supporting informal full screen communication standing up, on a vertically mounted flat screen. The area around the kitchen shelves is normally a semi-public zone where the

individual can be seen but not heard. However this could easily be changed into a public or a private zone. The public zone is normally located a little closer to the videoTORSO so that the resident must take a step forward to be heard. The screen can also be places in a horizontal position by twisting it. Ongoing activities aim at integrating the camera and the microphone into the videoTORSO at each side of the screen. In this way they are exposed and in function when the screen is in a vertical position for communication, and hidden and not functioning when the screen is in a horizontal position. The twisting of the screen is motor driven and controlled by the central logic. In this way the user can indicate with e.g. a gesture or a voice command, that he/she wishes to communicate and the screen automatically assumes the correct position. The speakers are placed above the screen and are always visible since the screen in the horizontal position can be used as a television, a web browser or ambient media. In this setting the core problem is to zoom into the audio space to a suitable range. This could perhaps be achieved by directed microphones which normally peak at a distance of 2 m and fade off rapidly at distances greater than 2.5 m.

A **comTABLE** located in the kitchen contains a computer and screen. The current uses for this table are two-fold. Firstly it enables a virtual dining guest to be a part of dinner through a video conference session that is displayed on the screen. Secondly it also make it possible to read for example a digital morning paper that appears in the table. This has two results.

Firstly, by placing a large display in the one of the table's unfolding parts it will become easy to adjust the screen for multiple use. In up-folded position the screen could be used for a remote invited dinner guest. In down-folded position could the screen be used for reading the morning paper or doing on-line ordering of groceries.

Secondly, by integrate the camera and microphone into the unfolding part control of the visual view becomes very physical (one interpretation of the ComZoon). By placing the camera into the frame we are hoping to find a natural syntax of adjusting the ComZoon – up-fold the display and the camera will view across the table, down-fold the display and the camera will stare into the roof.

The screen is located in a mobile frame on the rear end of the table. This VMC set-up can be used to read your interactive digital morning newspaper when seated at the rear end. Or the screen could also be placed vertically as a video representation of a guest on the screen during Sunday dinner. The integrated camera is located in the mobile frame so the control of the public space can be manipulated by lifting the frame up and down. This very physical interaction with the comTABLE provides an alternative to software and sensor based solutions.

A **deskTOP** and a **lapTOP** workplace, both for professional work in the home environment, are located in the combined home office and sleeping room. These two workplaces are held together with two boards completing the spatial definition. The public zone, where the resident can be seen and heard for example while participating in a video-conference, is indicated with a false ceiling equipped with integrated illumination. In these two settings, two cameras are used at each place. One is a dedicated handheld document camera for showing physical objects and the other a fixed camera that is adjusted so as to provide the talking head of the person.

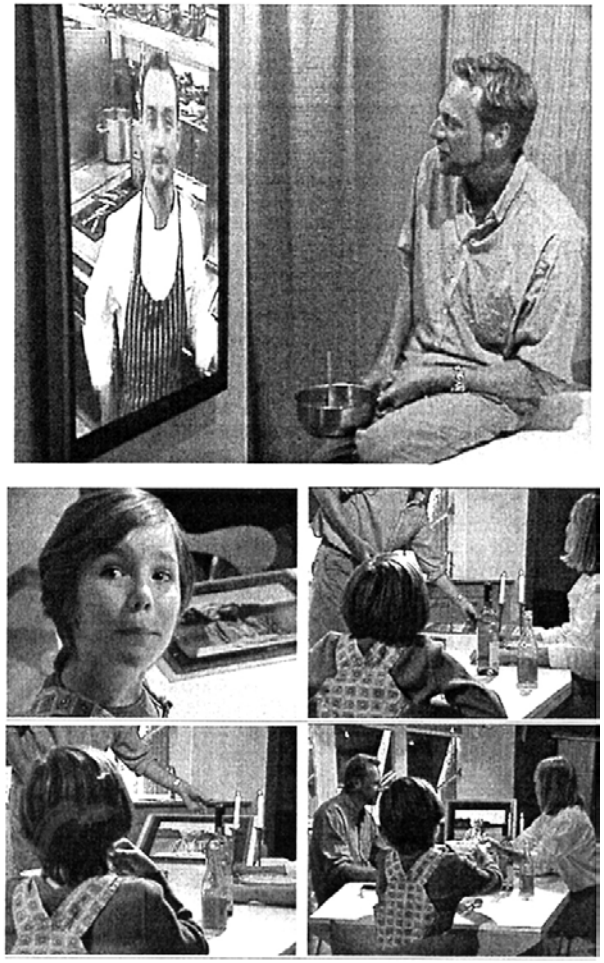

Figure 3. A videoTORSO for informal everyday communication.
Figure 4. ComTABLE for VMC in a dinner situation.

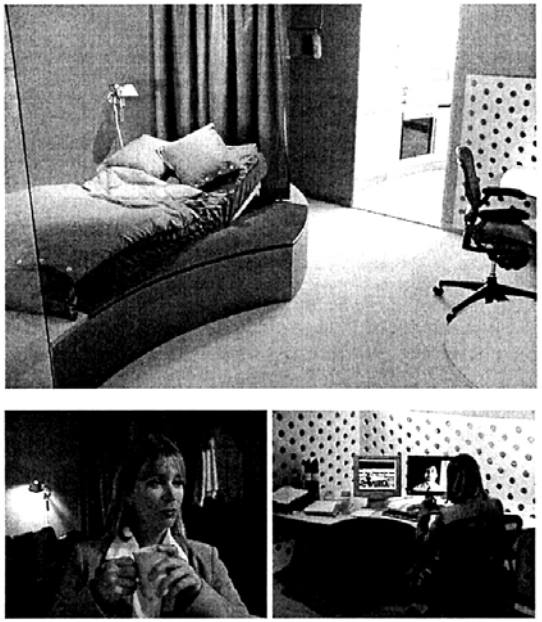

Figure 5. The deskTOP workplace with the wooden panel and lowered ceiling that indicates the *private zone*.

An **internetTV** with video communication facilities as well as connection to Internet services is located in the ceiling at the bed place. The border of the public is indicated and expressed by the shape of the wooden structure around the bed and a curtain behind it. Also in this setting, fixed cameras are used to simply define the fixed boundary.

A **mediaSPACE** located in the living room is the extension of the physical room creating a larger social space with the digital representation of another space. This is done on two parallel mounted 80" screens seamlessly integrated into one wall of the small living room. This comZONE is extended, and merged, with another room at distance. This space is primarily a public zone when in use and is limited by a curtain on its back wall. Realizing that this room is a mostly public space – when the VMC is in use - turns the problems upside down. In this case it instead becomes a challenge to both keep a broad overview and provide close-ups within the scene. Here we use a

technique from the VideoCafe system (Tollmar et al. 1998) and provide a dual video stream that could be used for both overviews and close-ups.

7 Conclusions from VMC in comHOME

The construction of the comHOME dwelling was finished during late 1998 and has since been taken into use as a laboratory. At this stage, rather than presenting results from specific evaluations, the points below can be considered as a number of ideas tested within the limitations of this full-scale experiment with no contradictions so far identified. Some early tentative conclusions from the design phase are:

- It is possible to introduce architectural expressions into the dwellings in order to support the resident in his/her understanding of, as well as experiencing the limits of, comZONES in the dwelling as far as the public (where you can be seen and heard) and the private (where you can not be seen nor heard) VMC issues are concerned

- It seems to give an added value to dwellings if information technology and architecture together can support the integration of VMC

- The changing use of the dwelling and the introduction of new ICT technologies seem to demand both new concepts for the general floor-plan layout as well as the specific spatial design

- Solutions for both sound and images are very complex and tend to be crucial for a successful integration of VMC set-ups in homes.
- Using none wearable microphones only, it appears to be difficult to create zones for audio which are as sharp and easily controlled as those of the video.

- In order to achieve a successful result, the development of new VMC set-ups for home environments should be closely linked to the general design of a smart home, both from a user and producer perspective.

- During the complex design process we have experienced, naturally several trade-offs have had to be made in both the general concept and the details of every specific VMC set-up. It has been very difficult to evaluate the effects many of these selections will have on the final real-life situation.

8 Future work

We still have a lot of work to do both regarding the hardware and software designs in order to make the VMC settings working properly. New directions in our research also include the use of sign/gesture language tracked by video to interact with the

technologies in the room. Further integration with the general smart environment is also underway.

Although lacking technical functionality we are at the moment performing user studies evaluating the architectural and technical design of some specific settings. A video, using professional actors and film-team, has been recorded and is now being edited. This video demonstrates putting the different VMC set-ups into a social context of everyday life.

Acknowledgments

This work has been performed with the kind collaboration of S-lab at Telia Networks in Farsta to whom we are deeply grateful, especially to Roland Bohman and Lasse Lindblad. We would like to thank our professors Ulf Keijer and Yngve Sundblad at the Swedish Royal Institute of Technology for their guidance. We would also like to thank Ingvar Sjöberg, Director of our Smart Things and Environments for Art and Daily Life Group at the Interactive Institute, as well as our other colleagues for their collaboration and invaluable support during this work.

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Paper 3

Paper title:

Private and Public Spaces – the Use of Video Mediated Communication in a Future Home Environment

Authors:

Stefan Junestrand, Konrad Tollmar, Sture Lenman & Björn Thuresson

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Also attached in the video belonging to the proceedings, time range: 31:28-38:24 (min./sec.). (The video is attached on a CD in the printed version of this book. Also available on: www.arch.kth.se/~junestrand.)

Private and Public Spaces - the Use of Video Mediated Communication in a Future Home Environment

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ABSTRACT

This video demonstration is based on scenarios of a family's everyday activities supported by video mediated communication (VMC). It was recorded in comHOME, a concept dwelling of the future. The principal issue explored in the comHOME project, and in the video, concerns various aspects of private and public spaces using VMC. The design concept is based on the integration of different comZONES (communication zones), where the resident can be seen and/or heard. The architectural space, then, in combination with information and communication technology (ICT) solutions forms an interface to the digital world. A main observation from the making of the video is that it is a very good complementary method in a complex design-process because of the focus on the user perspective.

Keywords

communication, comZONE, dwelling, home, ICT private, public, space, video mediated communication, VMC.

INTRODUCTION

Several trends indicate that VMC will become an important part of communication in our homes [1]. VMC can support and complement a wide range of activities in that context, e.g., studies, care of the elderly, professional work and leisure activities. It primarily addresses social and emotional aspects of communication, which is a requirement for communication in a domestic environment. However, dwellings are ill suited for VMC due to, e.g., unsatisfactory lighting conditions, floor-plan layout and spatial design. Also, current VMC solutions for collaborative work are not well adapted for the home.

comZONES

The comHOME dwelling, which was used for recording the video, is a laboratory and a showroom for a dwelling of the future [2]. The comHOME project covers several aspects of future dwellings, such as making the apartment smart, but the primary goal has been to develop and integrate VMC solutions into a home. The design of the dwelling is based on the idea of creating different comZONES to support the demands for both private and public digital spaces within the home environment [3]. The comZONEs have the following characteristics: In an inner, public zone, one can be both seen and heard. In a middle, semi-public zone, one can be seen but not heard. In an outer, private zone, one can neither be seen nor heard. These spatial characteristics may also vary over time, depending on the scenario of use.

The principal architectural issue was the establishment of the mental and physical boundaries between the public and the private in the comZONES, i.e., to uphold the demand of neither being seen nor heard - when so desired. The comZONES are expressed by technical solutions such as screens and cameras, but also through the use of architecture - spatial forms, colors, light and materials. Thus, the architectural space in combination with ICT solutions forms an interface to the digital world.

The creation of the different comZONES in the rooms of comHOME is a major technical undertaking. The ongoing development aims at the control of focus depth and field of view for video space. The control of the audio space is more complex, however. The fairly precise video space can not be matched with equally well-defined boundaries in audio space. New technology that might solve part of this problem is array-microphones, spatially directed loudspeakers, and real-time image and audio manipulation that can filter background actions and sounds.

An additional means of protecting privacy while maintaining continual contact is to, in some situations, replace VMC with a shared, 3D digital environment (DE). Here, rendered user representations provide an abstraction of information that can act as a filter for what is kept private or made public [4].

THE SCENARIOS IN THE VIDEO

The video shows four scenarios, each one demonstrating the idea and some functions of each comZONE.

workPLACE

The workPLACE is a place for professional communication, located in the combined home office and bedroom. A table with two sideboards and a lowered ceiling with integrated lighting spatially defines the inner public zone, where the resident can be seen and heard. In the video Christine moves in and out of this public zone illustrating the function of not being heard and seen when in the private zone. The use of a DE for communication is also illustrated at the workPLACE. Problems of privacy intrusion while a participant is in the public zone are dealt with by abstraction of information, while still providing pertinent information. The DE also serves as a vehicle for initiating richer forms of communication, such as VMC.

Figure 1. Upper left: workPLACE, upper right: videoTORSO, lower left: comTABLE, lower right: mediaSPACE.

videoTORSO

The videoTORSO, a flat screen that can be twisted between vertical and horizontal position by voice command, is a set-up for informal everyday communication in the kitchen. The public zone is normally located in a defined area around the videoTORSO and the user must step up to it in order to be heard. But the public space could also be tracking a user who moves around in the room. The scenario in the movie shows Tony giving a voice command to the videoTORSO to establish a call and then moving up to the public zone. The presence of Christine and the daughter illustrates the semi-public zone along the kitchen fittings.

comTABLE

The comTABLE in the kitchen contains a computer as well as a touch screen, a camera, a microphone and loudspeakers in a mobile frame at the rear end of the table. The use for this table is two-fold. In an upright position, it enables a virtual guest to participate in a dinner through VMC. Secondly it could be used for, e.g., reading a digital morning paper or doing online ordering of groceries. By placing the camera in the frame the syntax for adjusting the comZONE becomes clear - fold up the display for a camera view around the table - fold down the display, and the camera will be turned off, although the image appears, as shown in the scenario.

mediaSPACE

The mediaSPACE in the living-room extends the physical room by connecting to a distant space, presented on two 80" screens, mounted side by side and seamlessly integrated into one wall. Thus, this comZONE creates a larger social space. The mediaSPACE is primarily a public zone and is limited by a curtain on its back wall. The fact that this room is a public space when VMC is active creates a different set of problems. It becomes a challenge to both keep an overview and to provide close-ups within the scene. The video illustrates how Christine and Tony participate in a public event and then simply shut the system off for returning to their private sphere.

CONCLUSIONS

The most interesting experience from making the video is that it has been a very good complementary method in the design of the comZONES because of the extreme focus on the user perspective. Also, writing the script helped us realize alternative, often better, ways to use the systems than the ones we had imagined during design. E.g., that the arrangement of the multiple screens in the workPLACE is a very complex issue that has to be studied further, and that more flexiblity is needed, e.g., to choose portrait or landscape formats when using the videoTORSO, the comTABLE or the workPLACE.

ACKNOWLEDGEMENTS

This work has been performed in collaboration with S-lab at Telia Networks. Yngve Sundblad, head of CID at the Royal Institute of Technology, and Ingvar Sjöberg, director of the Smart Things and Environments for Art and Daily Life Group at the Interactive Institute, have given both practical and theoretical guidance. Emanuel Hägglund at Gluggen Production has given excellent advice.

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Paper 4

Paper title:

User Study of Video Mediated Communication in the Domestic Environment with Intellectually Disabled Persons

Authors:

Stefan Junestrand, Ulf Keijer, Göran Molin & Konrad Tollmar

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User Study of Video-Mediated Communication in the Domestic Environment With Intellectually Disabled Persons

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A user study of video-mediated communication (VMC) involving six persons with mild intellectual disability is presented. It took place at comHOME, a full-scale model of an apartment of the future, showing innovative architectural and technical designs with regard to the integration of VMC into the domestic environment. Two different zones for VMC, comZONES, in the apartment were tested, the *videoTORSO* (a large-screen set-up for informal everyday communication) and the *workPLACE* (a place for professional work tasks). The purpose of the study was to get a deeper understanding of how people use these comZONES. The final discussion points out that the comZONES seem to be interpreted correctly and to function aptly in relation to the participants in the study. An assumed explanation is that spatial recognition is a very fundamental human function and thus less significant with regard to the mental capacity of the individual.

This work has been performed in collaboration with S-lab at Skanova, Stockholm. We would like to mention especially Roland Bohman and Lasse Lindblad at the S-lab. The close collaboration with Kungsholmens Dagliga Verksamhet and the fine work of Carina Berglund and Marianne von Döbeln has been indispensable for the study. The study is a part of a project financed by the Swedish Council for Building Research, the Swedish Council for Communication Research, and the Swedish Handicap Institute.

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1. BACKGROUND

The development of the information and communication technologies (ICT) is currently very rapid, and several trends indicate that video-mediated communication (VMC) will become an important part of the communication systems in our homes (Kraut & Fish, 1997). VMC can support and complement a wide range of home-based activities such as professional work, study, leisure activities, and care of the elderly and others needing care and surveillance. These activities can take place despite the separation in space. When listing current common activities, it becomes obvious that a large portion of what could be called "living processes" will be prone to change with the increasing number of applications of ICT in our homes.

Studies indicate that long-term change of the process of "living-in-our-homes" is reflected in the architecture. This change is often slow in the beginning. With increasing momentum, the change manifests itself successively. Preliminary findings related to living processes indicate that our homes will be the place for more compound activities in the future, with more complex relations in time and space. At the same time, these processes will be supported by ICT (Junestrand & Tollmar, 1998).

Obviously, VMC and other ICT put specific new demands on the design of the dwelling. Generally speaking, dwellings are not very well suited for VMC, for example, due to unsatisfactory acoustics, light conditions, technical installations, floor-plan layout, or spatial design. Creating dwellings that are fitted for the new needs of the new information society seems to be a highly intriguing but nonetheless very timely and adequate problem. In this article, a user study that forms a part of the overall design process for ICT in our homes is presented.

2. THE comHOME APARTMENT—THE PLACE OF THE STUDY

A conceptual apartment of the future called comHOME was designed as a laboratory and as a showroom for a dwelling of the future. The primary goal was to develop and integrate VMC solutions into a simulated home setting (see Figure 1). The design of the dwelling is based on the idea of creating different comZONES—zones for VMC—to support the demands for both private and public spaces within the home environment. The comZONES are classified as one or more of the following: an inner, public zone, in which one can be both seen and heard; a middle, semipublic zone in which one can be seen but not heard; and an outer, private zone in which one can neither be seen nor heard. The different comZONES are expressed by technical solutions such as a screen and a camera and by the use of architecture in terms of spatial forms, colors, light, and materials. The architectural space can, then, in combination with ICT solutions, form an interface to the digital world.

The principal architectural issue was the establishment of mental and physical boundaries between the private and the public digital places in the VMC-supported communication zones, that is, to uphold the absolute demand of not being seen or heard when so desired. Dourish (1997) pointed out the contradiction in the nature of media spaces as hybrid physical or virtual environments and that public and private aspects need to be well balanced to gain acceptance.

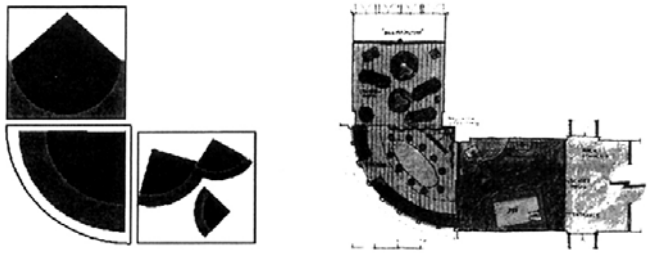

FIGURE 1 Left: Conceptual design of the floor plan indicating the comZONES in the comHOME apartment. In the inner black zone, the individual can be both seen and heard by the VMC equipment. In the outer grey zone, the resident might only be seen but not heard. In the surrounding white zone, the person can neither be seen nor heard. The zones do vary in time and space. Right: Floor-plan sketch of the dwelling. The entrance is at the lower right. The middle room at the bottom is a combined telework and sleeping room. To the lower left is a kitchen, and to the upper left is a living room.

Further, the design takes into consideration both the inside-out perspective (how the outer world is perceived through VMC from within the home) and the outside-in perspectives (how the dwelling is perceived from places outside the dwelling) supported by VMC (Junestrand & Tollmar, 1999). In this study, only the former perspective is effective.

The major difference between the comHOME and a traditional VMC office set-up is the fact that the home is a radically different place compared to the more controlled office environment, in which such features as poor lighting and audio conditions are considered normative rather than a rare exception. In this study, very favorable conditions were maintained, in order not to introduce secondary restrictions. The technical design concept of the video and audio spaces in comHOME is based on several short-range cameras and microphones mapped and routed through a common media switch.

The comHOME environment offered a favorable opportunity to try novel communication technologies with regard to different and varying needs of people with disabilities. The concept of "design-for-all" is already very much acknowledged and will be more so in the future. The participation of persons with intellectual disabilities will contribute substantially to the development of knowledge in the field. The opportunity constituted an excellent possibility to bring in essential requirements early in the design process that may be more difficult to introduce later.

2.1. videoTORSO

The videoTORSO is a set-up that enables informal communication with a person as if he or she is in the doorway of a room. The set-up consists of (see Figure 2):

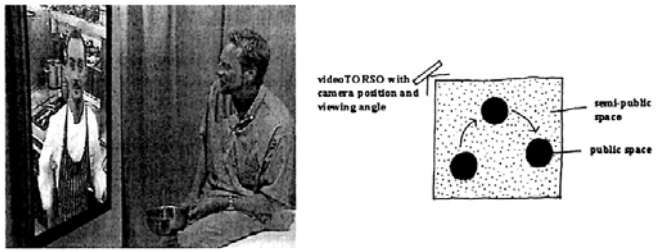

FIGURE 2 Left: An illustration of how the videoTORSO could be used in an everyday situation. Right: A floor-plan sketch of the function of the videoTORSO indicates public and semipublic places.

- A large flat screen, which can be adjusted in height, placed on a wall, allowing for both short and tall users.
- Loudspeakers just above each side of the screen, thus making the sound appear to be coming from the videoTORSO screen.
- A camera placed as close as possible to the screen at the eye level of the person appearing on the screen.
- Microphones placed just beside the screen.
- Software for video communication.

These parts are integrated in one single device, the videoTORSO, which makes it possible to convey social and emotional qualities similar to those that could be attributed to a person standing in the doorway of the room. The location of the videoTORSO in the room is also essential. If the objective is to simulate a person standing in the room, it is important to locate the videoTORSO at a place that is comfortable and natural to turn to. The confines of the view angles of the camera also have to be controlled. Architectural bounds and software and hardware solutions can accomplish this. The sound in the room is captured mainly from the person having the conversation. If several persons participate, the sound from all of them is recognized. People in the room not participating in the conversation only appear as images producing background sound and images and thus are semipublic. The videoTORSO might well simulate a person in the room. The person at the other side of the screen, however, will not at the moment experience himself or herself as being in the room. The set-up thus primarily supports the inside-out perspective, as discussed previously.

2.2. workPLACE

The use of VMC for professional work or study activities in a home environment could cause many problems, both for the person performing the work and for the

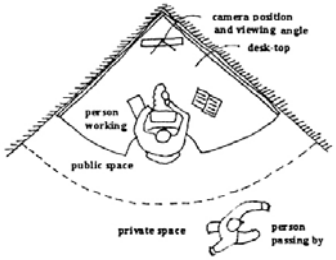

FIGURE 3 A floor-plan sketch of the functions of the workPLACE.

persons around and behind the workplace, whose integrity could be disturbed and who may feel uncomfortable. Therefore, it should be important that one is able to feel private, that is, not visible or heard, and generally comfortable when standing, sitting, or passing behind someone using a VMC set-up for professional work.

In the set-up developed for the comHOME project, the workPLACE is placed in a combined home office and bedroom, which causes the camera to view not only the person at work, but the bed behind as well. This pushes the aspects of private and public to its extreme and requires the development of architectural measures that facilitate the interpretation of the borders between private and public spaces, as well as complementary ICT devices and software. A table with two sideboards and a lowered ceiling with integrated light spatially defines the public zone, in which the user can be seen and heard. The zone outside, with the bed, is private (see Figures 3 and 4).

3. A MULTIDISCIPLINARY STUDY

The study is truly multidisciplinary. Knowledge and theory have to be derived from a number of different disciplines and, if possible, brought together to form a

FIGURE 4 Left and Center: The user appears in the workPLACE as in the real home environment using the video conference system. Right: From the remote place (the partner in the VMC conversation), the user appears to be in an office environment.

unified view of the subject. In this article, however, we confine our discussion to the aspects most relevant for the conducted study, that is,

- the intellectual disability,
- the architectural design,
- the technology of VMC.

3.1 Intellectual Disability

The basic principles concerning intellectual disability in our work start with the theory that Gunnar Kylén (1983) developed during several decades at the Ala Research Foundation in Sweden. He studied the nature of intellectual disability and its significance for the cognitive development of a human being and his or her interaction with the physical and social environment. Intellectual disability manifests itself by increasing difficulties in responding properly when interacting with the environment with higher levels of abstraction. This includes the ability to receive, process, store, and internalize information. Four levels of abstraction were proposed, which to a large extent were influenced by Jean Piaget and related theories of stages in human cognitive development (Kylén, 1983). Although these theories today are questionable, they were valuable for how Kylén presented and structured his findings in this field of research.

Kylén (1983) chose to denominate the attainable abstraction levels of intellectually handicapped persons as A (profound intellectual disability), B (moderate), and C (mild). Broadly, level A corresponds to a level of intelligence of a child less than 2 years of age, level B 2 to 7 years, and level C 7 to 12. The fourth level, D, can only be reached by people with what we consider as normal intelligence. Kylén arrived at the conclusion, which has been used instrumentally in practice, that different individuals pass from childhood to adult through the same levels of ability of abstract reasoning. Some, however, halt at some lower level, whereas most people advance to a level considered to be normal for the population. The three levels of intellectual disability, A, B, and C, were considered appropriate for the classification in this study. In accordance to Kylén's findings, individuals with intellectual disability were found to have substantial reductions in their capacity of reasoning and difficulties in relating to the surrounding world. The reduction of capacity was revealed successively during the individual's development period. The medical descriptions vary and include cerebral palsy, Downs syndrome, minimal brain dysfunction, and deficits in attention, motor control, and perception. These people have difficulties with concepts like space, time, quality, quantity, and cause. In principle, these five categories are used also by Kylén. For this study, only persons of level C (mild intellectual disability) were engaged.

3.2. Architectural Design

The design issues of the home environments have a primary methodological relation with the explorative and creative development of the functional period of in-

ternational architecture. This refers mainly to the development of new conceptual and practical ideas for the dwelling that took place at the beginning of the 20th century. There is also a direct reference to more formal aspects of architectural design as far as cognitive and psychological aspects are concerned (i.e., Hall, 1966; Weber, 1995). Architectural projects and research related to the use of IT in the home environment appear, in general, to be more focused on the technology than on the architectural design. One exception is the work done by Caso and Tacken (1993) that concerns the analysis and classification of different IT-supported activities that can be carried out in the home environment. These studies aim at presenting a conceptual organization and allocation of IT-supported activities in time and space within the home.

3.3. The Technology of VMC

Naturally, as VMC moves from the office environment to the domestic environment, one could learn many important lessons from research of video communication in the computer-supported cooperative work community (Kraut, Egido, & Galegher, 1990). In the context of video communication for remote collaboration, the major focus has been on whether the video media actually improve conversation (Whittaker, 1995). In more current research in media space (Dourish, Adler, Bellotti, & Henderson, 1996), one could see a trend toward nonquantitative studies in an attempt to specify users' perception and awareness of others' presence. The presence or absence of a social context deeply influences how conversations proceed and their results. Studies in video communication have indicated that the main contribution of the video media is the rich social context. It has hence been argued that by improvements of the media quality, it will be easier to initiate informal communication and the conversation will flow more smoothly (Tang & Isaak, 1993).

Our principal premise, though, is that most imitations of architectural and urban spaces and places that are used in communication systems are too crude and superficial. Designers of today's electronic communication media unfortunately do not advocate and develop the architectural metaphors far enough. Fish, Kraut, and Chalfonte (1990) reflected on difficulties in a self-critical analysis of the Bellcore Cruiser system—"the mechanisms that were supported in the Cruiser system were abrupt, intrusive, and lacking in subtlety" (p. 10). General guidelines are to build the interface as physical and transparently as possible. Ideally, one will be able to use one's body in the room, and not devices, as the main interaction device. The "smart" or "reactive" artifacts will use information from devices such as motion detectors, processed video, and contact sensors to control the equipment of the meeting room (Junestrand &Tollmar, 1999).

4. THE STUDY

In spring 1999, the design and construction of the comZONES were nearly completed with systems almost working. At this point, it became important to involve users to evaluate some aspects of the ideas we had about the design and to get new

input for further development of the systems. We considered it especially interesting to be able to involve users with intellectual disability to identify as many questions and problems as possible that were not equally easy to catch with a more narrow selection of test persons. A control group consisting of six persons with no obvious disability was tested too. We will not discuss this aspect further, as comparisons between the two groups were not a primary objective of the study.

4.1. The Design of the Study

The study aimed at evaluating two of the comZONES in the comHOME apartment, the videoTORSO and the workPLACE, as described previously. The study took place in the apartment comHOME located at Skanova's premises in Farsta, Stockholm, Sweden. The tests were conducted during 3 days in June, 1999.

As mentioned, two user groups, each consisting of six persons, participated in the study. One of the groups consisted of people with intellectual disabilities who worked at a special workplace, for people with intellectual disabilities, in Stockholm. The persons in this group were selected in collaboration with the staff at Kungsholmens Dagliga Verksamhet (KDV; their daily workplace). The staff suggested a selection of persons whom they considered the most interested and suited to participate. Six persons were engaged: four men and two women. The group turned out to be rather young (25 to 45 years old). Some basic characteristics of these persons are found in Table 1. It should be noted that all participants are sup-

Table 1: Some Characteristics of the Six Disabled Persons Involved in the Study

Age (years)	*Sex*	*Medical diagnosis*	*Characteristics*
45	M	CP-injury at birth Dysartri	P. can express two to three words after each other. Difficulties in being understood at verbal communication. Communicates through single words, body language, and pictures.
31	M	No diagnosis but corresponds to the DAMP criterion	Concentration difficulties. Difficulties in understanding instructions, especially putting instructions into practice. Lack of mobility and perception.
25	F	Downs syndrome	In addition, defective vision on both eyes.
21	M	MDB/DAMP	P. is slightly intellectually handicapped. No physical handicap.
31	M	CP-injury at birth	Able to walk at 8 years of age. Difficulties to be understood through spoken language, due to difficulties in articulation. Communicates using sign language. Understands spoken language.
43	F	Spinal cord injury at birth	P. is slightly intellectually handicapped. Uses a wheelchair and has a leg prosthesis.

Note: CP=cerebral palsy; DAMP = deficits in attention, motor control and perception; MDB = minimal brain dysfunction.

posed to belong to group C according to Kylén's (1983) classification, that is, persons with mild intellectual disability. Some of the users in the group had personal experience with the use of a personal computer (PC).

4.2. Methods

The apartment was shown via a video (shot by one of the staff of KDV) to the people with intellectual disabilities several weeks before the actual study began. The study was also presented at a meeting at KDV in which the majority of the intellectually disabled participated.

The main method used for the study was video-recorded observations. The observations were carried out around the two different set-ups, the videoTORSO and the workPLACE. In each of these set-ups, the user had to perform certain tasks that aimed at getting the individual to use the system and some of its functions. Users where sometimes "pushed" in some direction—for example, asked to move to a place in the room where they thought they could not be seen by the remote person, or to move closer to the screen—to be able to capture changes in their behavior. The users where guided by three persons during the interview. One was a person in the room guiding the test. Although some intermediate instructions were given, the intention was not to interrupt or interact. The other person was the remote video communication partner. There was also a person from KDV known to the user in the room. This person stayed in the room primarily to make the user feel more secure and in case the user had to be supported. This person, though, was to stay in the background. The observations aimed at studying the use and behavior of the users in action. Later analysis aimed at finding out if there was any "normal" use of the systems as well as to find interesting differences between different individuals of both groups.

A short, semistructured interview was carried out with each user individually, without the system running, as a follow-up of the experience. We thereby acquired more understanding about the study and clarified some remaining points of interest.

4.3. The Tests

The study took about 1 hr for each test person and consisted of the consecutive testing of the two comZONES described earlier. Initially the user study started with a welcome and a short presentation of the comHOME apartment and a description of the study. Each test situation started with a very brief explanation of the functions of and the ideas behind the comZONE to be tested. This part worked fine and in general there was no problem to get the users to start to use the system, although in some cases it was difficult to get the user to understand how the system worked before trying it. The person from KDV normally didn't need to support the test person to any extent at this introductory interview. The two test set-ups are illustrated in Figures 5 and 6.

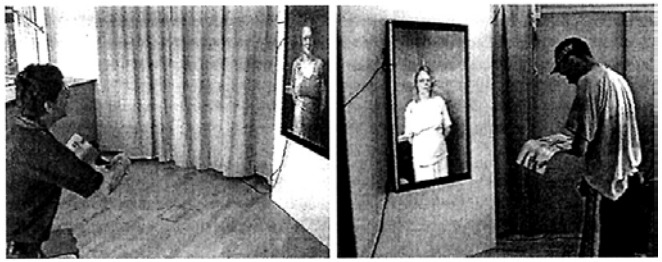

FIGURE 5 Left: A 45-year-old male user with cerebral palsy shows the contents of a saucepan to the remote communication partner. Right: A 21-year-old man with minimal brain dysfunction and deficits in attention, motor control, and perception reads out loud the content of directions for a use folder at the videoTORSO.

For the videoTORSO, the person on the screen appeared automatically without any interaction of the user. As for the workPLACE, the user had to enter the public zone under the lowered ceiling to make the person on the screen appear. Each session took 10 to 20 min, and the person on the screen monitored the interviews. The support person in the room interacted only when the communication tended to halt. Observations and interviews of each of the two comZONEs were recorded on video.

The six interviews with the disabled persons were then followed by the tests with the nondisabled user group. The tests with the nondisabled group where car-

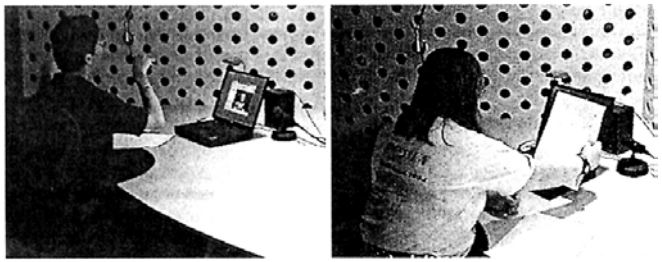

FIGURE 6 Left: A 45-year-old male user with cerebral palsy tries to use sign language on the desk-top video set-up, but it shows up to be almost impossible due to the small image and low resolution. Right: A 25-year-old women with Downs syndrome tries to show the text that she has written on the paper to the remote communication partner by putting the paper in front of the image. (She did not understand that the remote person saw her through the video camera attached at the upper left corner of the portable PC.)

ried out in the same way as with the first group. The principle differences were that the tests generally continued a little longer and the nondisabled test people did not know the person on the screen, contrary to the case with the disabled persons.

The design of the comZONES was slightly modified during the study from the normal set-up in the comHOME apartment. This was done with regard to the applied technology and to the adjustment of the limits of the private and public zones. These adjustments became necessary because the technical system of tracking the position of the persons was not yet working properly. Also, the systems had to be turned on and off manually.

4.4. videoTORSO

The most significant feature with regard to the intended function of the videoTORSO set-up was that the whole room practically formed a public zone. The only restrictions for the public space in the room were the limitations due to the camera angles and the fact that the comZONE was turned on and turned off by the interviewer at the start and the end of the test sessions. No tracking function was assigned to the camera. A tracking function was in fact an early idea that could not be implemented for the study reported here.

The set-up for the videoTORSO consisted of a 50-in. plasma screen orientated vertically. A small video camera was mounted on the side of the monitor. A loudspeaker and a microphone were positioned on top of the stand. In the room of the remote place, a video camera was mounted at eye level and in front of the monitor. The reason for this was to create a direct sensation of eye-to-eye contact, in spite of obscuring a minor part of the visual field (see Figure 5). The person conducting the test was then placed in front of the camera at a distance of approximately 1.5 meters, which gave an almost exact two-dimensional representation of the people's length on the wide-screen monitor.

4.5. workPLACE

Regarding the workPLACE, there was only a public zone and a private zone. No semipublic zone was simulated. The idea was that it should be made as easy as possible to evaluate and test the principal research question of the workPLACE, that is, how the spatial design indicators where used and interpreted. Therefore, the difference was made clearer with a public zone, the inner area indicated by the cloud-like ceiling and the shape of the table, and a private zone as the outer area. The turning on and turning off of the system was supposed to function through the user's positioning of himself or herself in the room, by moving into and out of the public zone. This function was simulated manually in the tests, although the users seem not to have noticed that. The set-up of the workPLACE consisted of a laptop computer positioned in the middle of the desk. On the top of the laptop, a PC camera was positioned and connected to the computer. The video communication was established through a video conferencing program. A microphone and loudspeaker

were placed beside the computer. The size of the image on the 15-in. monitor was approximately 7 in. and showed the head and shoulders of the remote person. The person monitoring the test was once again positioned in the room of the remote place, this time facing a video camera connected to a PC.

5. DISCUSSION

The involvement of users with intellectual disabilities has been very valuable and has clearly shown the need for simple and clear set-ups with regard to both technology and spatial design. The close cooperation with KDV during the whole period of the user tests—from the planning to the follow-up of the study—prevented us from committing simple mistakes. It also secured a smooth and enjoyable interview process and provided us with plenty of valuable background information as well as interesting opportunities for reflection.

A direct result of the collaboration in the planning of the study was that the semipublic zone, in which one can be seen but not heard, was removed at the workPLACE. This was done to make the boundary between the public and private clearer to the user ("what you see—and hear—is what you get" is given an extended interpretation here). This phenomenon of having clearer boundaries than in this first set-up is something to pursue in the future development of this specific comZONE.

5.1. The Method

The actual test situations worked out well, and it seemed easy for the users to use the systems. The participants did not exhibit much fear of the technology or of the very test situation. This could, however, be an outcome from the earlier contacts with the users and the presentations of the study. The follow-up interviews did not offer much additional information. The participants had difficulties in reflecting on their own experiences, most likely a consequence of their disability.

5.2. The videoTORSO

The key issue of the understanding of the idea of the videoTORSO is the question of representation. The fact that the screen figure is not a real person is obvious even for the individuals with intellectual disability. As mentioned, Kylén (1983) chose to call the ability of abstraction levels of intellectually handicapped people A, B, and C. On level B or higher, which refers to all participants in this study, picture symbols (e.g., photographs or mirror images) are understood as symbols. However, this does not explain how the representation produced feels for an individual. By observing the participants' behavior while engaging in videoTORSO communication though, it appears that the behavior is similar to what would be expected for face-to-face communication. In this regard, there is no noticeable dif-

ference between the disabled and the nondisabled. The physical size of the pictorial representation on the screen is close to a 1:1 relation to the real person, displaying about three quarters of the full body. By acting as a person present in the same place as the representation, the remote person seems to get similar responses to his or her actions as for the normal face-to-face communication. The user receives both mental and emotional confirmation when acting. Also, a flavor of the remote person being present in the room seems to be felt. One of the intentions of the design of the videoTORSO as a VMC artifact was to allow socially oriented communication, taking into considerations the special limitations and possibilities that individuals with intellectual disability show. A conclusion from this study is that the videoTORSO has enabled the communication it was designed for. Another conclusion could be that it has a potential for all kind of users, maybe even for individuals with more severe intellectual disability than those engaged in this study.

In several ways, the videoTORSO could be designed for more realistic tests. It is, for example, not possible to keep eye contact when moving around in the room. In fact, it is not even possible to look each other straight in the eye, because the camera is not placed in the middle of the videoTORSO. Depending on the camera angle and the participants' different heights, the point where natural eye contact is best perceived is not stationary, and sometimes it is not even possible to find the correct camera angle.

Observations in the study show that participants chose to stand farther away from the person on the screen compared to how close they would have stood during a face-to-face communication. Why not as close as in normal conversation, one may ask? One aspect could be the aforementioned difficulties of finding an angle for natural eye contact, or it may be that it is unpleasant to be close to a bright, 50-in. video screen. Or is it the representation on the screen that is unpleasant to get close to? Yet another aspect could be that getting too close to the small dots on the screen causes the built-up representation to become visible; in other words, the illusion of reality is lost. These and other aspects should be taken into account in future studies of the VMC artifact, the videoTORSO.

5.3. The workPLACE

Regarding the workPLACE, the principal cognitive focus is the intellectual, emotional, and physical boundaries between public and private spaces in the VMC-supported communications zones. Can the workPLACE as a VMC artifact allow work-oriented communication, considering the specific restrictions that individuals with intellectual disability are subjected to? Observations from the tests show that some of the participants have a rather clear apprehension of the boundaries of the communication zone, whereas others do not reveal any conscious behavior when entering or leaving the communication zone. Indications support the assumption that the participants differ, at first in conceiving spatial and symbolic expressions, and, second, in imaging the cause and effect of their conception. To get a better understanding of different conceptions of the communication zone, we

have to look at the way in which the communication zone is defined and how the design is related to different levels of abstraction.

First, the communication zone is defined by its capability of communication: when inside the zone, one is seen and heard; after leaving the zone, the communication discontinues and one is no longer seen or heard. Apparently it is not obvious that an experience of starting a computer and a communication session by the positioning of one's body in a predefined way will lead to a comprehension of the existence of a communication zone and its boundaries. At least two questions emerge: "Is it really me who started the communication?" and "What did I do to start the communication?" Both these questions need some further exploration. The answer could very well be "I don't know" to both questions.

If one understands how the communication really was started, one possible effect will be to try again and see what happens. After a number of attempts, a perception of a communication zone, albeit invisible, may emerge. This invisible communication zone is probably conceivable only on a high level of abstraction. Disabled individuals may experience difficulties if not supported by less abstract spatial and symbolic expressions. The first step to make the invisible communication zone more comprehensible on a less abstract level is to render the zone visible. This was done at the design of the workPLACE by lowering the ceiling of the communication zone and keeping it at normal height outside the zone.

Well under the lowered ceiling, one is seen and heard; by entering this part of the space, the communication starts. This realized lowered ceiling should obviously be less abstract and more concrete than an invisible communication zone as such, but still, it constitutes an abstract spatial expression. The spatial expression is more concrete, but to a certain degree the height of the ceiling also has an undefined and unclear symbolic connotation to the concrete world. In the study, the lowered ceiling is labeled "the cloud." The similarity between the lowered ceiling and a cloud may be apprehensible only on a high level of abstraction and therefore not adequate for individuals with intellectual disability. After the tests were completed, the question arose if the use of other possible notations related to more concrete objects, for example "the cave" or "the roof," would have been easier concepts to grasp. On the other hand, the label or metaphor may be of minor importance; in reality the design of the workPLACE is much more crucial for the interpretation of how the comZONEs work.

The communication starts effectively when the test person sits down on the chair and looks at the screen in front of himself or herself. Several spatial impressions emerge when the communication starts. However, only a limited number of spatial clues describe the boundaries of the communication zone, which might not be appropriate in this complex situation, just when the communication opens. This phenomenon remains to be further examined and evaluated.

Another reflection is that the public space, represented with a lowered ceiling, should be higher—not lower—than the surrounding space to better correspond cognitively to an open, public space. At the same time, the private space should have a lower ceiling to better correspond to our intuitive comprehension of a private place.

5.4. System Quality

There is a clear difference in the visual quality of the VMC between the videoTORSO and the workPLACE. The most obvious is the small size of the computer screen at the workPLACE, offering a picture of some 7 in., compared to 50 in. for the videoTORSO. The other significant difference related to the visual quality is that pictures displayed at the workPLACE screen are not perceived as being dynamic. At the workPLACE, the user seems to have difficulties reading facial expressions and capturing body language. It is likely that this will affect communication and its outcome. A similar discussion could be devoted to sound and voice recognition. The technology affects profoundly the conditions for an effective dialogue, and still more so for the specific group of people studied here.

5.5. Private and Public Zones

Design can aid individuals in observing the cause and effect at different levels of abstraction. The private and public zones in the workPLACE can be addressed by design experiments. Although some of users did not intellectually understand a certain function, all were more or less able to control the function of the public and private spaces by moving their bodies in and out. The concept of private and public zones is obviously general. If the design supports the cognition of private and public zones at a lower level of abstraction, it will probably also increase the possibilities for others as well. The theories of different stages in human cognitive development might be one way to understand how to design artifacts and the environment to best serve human needs. Intellectual capacity enhances understanding. Understanding, however, is often not necessary for an individual to act in his or her best interest. Relying on emotions may offer better results. As Kylén (1983) described, the thinking process for decisions and weighting is made between emotional information and knowledge. This is important because the intellectual disability is not related directly to the emotional capacity but can indirectly affect and limit the emotional development. Generally speaking, much insight for the development of genuine user-oriented interfaces could be gained by acknowledging emotional capabilities. Studies with persons with intellectual disabilities may be an important source in this respect.

5.6. The Design of a Home

How the architectural design supports the individual in his or her home environment depends on the level of abstraction of the design. This has to be taken into account when designing homes for people with intellectual disability.

> If the brain matures slower and remains at a lower level than average then this will result in a biological conditioned limit to the abstraction level of thought which cannot be increased through training. But the experiences gained at that level can be rich, adequate and extensive. (Kylén, 1983, p. 15).

The design of the home environment, especially with the integration of VMC, gives the home a certain structure and symbolic meaning. This should be taken into account as the design can be realized at different levels of abstraction.

6. RESULTS

The idea of private and public spaces seems to have been captured by the test persons in this study. Our experience is that people with intellectual disabilities can use VMC well. This is generally an environment rich in information. A rich media environment also permits a user with less physical or intellectual capacity to compensate some aspects of communication by other qualities that the user possesses. Some other results to be shown are:

- The users generally did not comprehend intellectually the function and concept of private and public zones at the workPLACE set-up. But they were all nonetheless more or less able to control the function of the comZONE by moving their bodies in and out of the zone in which they were supposed to be visible. With further development of the concept of comZONES, the boundaries between the public and private zones ought to be clearer and more apparent to the users; that is, it seems to be important to support the different comZONES on an intuitive and concrete level.
- The participants' behavior when engaging in the videoTORSO communication is similar to what would be expected in a face-to-face communication. Principally, all participants act as if the person is present at the location at the videoTORSO, and there is no significant difference in the behavior between the disabled and nondisabled test persons. The only noticeable differences between the two groups are that the nondisabled directly understand that the camera is located just outside the screen and that they therefore are seen from that direction and not from the very eyes of the person on the screen. In general, all test persons chose to put themselves further away from the screen compared to what would have been a normal distance in a face-to-face interaction.
- An average level of abstraction—that is, a normal level—when designing artifacts for the home environment will not automatically include persons with reduced intellectual capacity or understanding of the functions of a particular home. Conversely, however, design can aid these persons to observe cause and effect at different levels of abstraction. Relying on emotions rather than on consciousness only may offer still better outcomes. Taking this into consideration will also increase the possibilities for other groups—for example, children—and for all users.
- In the development of user-oriented interfaces, much insight could be gained by acknowledging both emotional and intellectual capabilities. Studies including persons with intellectual disabilities could be considered as an important source of information in this respect for future studies.

• The necessity of simple and clear designs with regard to both technology and spatial forms are strongly confirmed by this introductory study. This result has wider implications, and such a result ought to be taken into consideration when designing artifacts generally and specifically, for example, for elderly people living in their homes.

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Paper 5

Paper title:
Private and Public Digital Domestic Spaces

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Private and public digital domestic spaces

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With the introduction of information and communication technologies into our homes and the different physical and communicative expressions this implies for our living spaces the concepts of being *private* and of being *public* become crucial. In this paper, we introduce *A Pattern Language*, developed by Christopher Alexander in the 1970s, in order to handle these problems systematically. The presentation formally follows Alexander's structure in five cases all related to practical experiments on being private and public at home. We start with a number of concrete user situations related to human–computer interaction. Social and communicative phenomena or possibilities end up in novel design patterns at the interface between an architectural and a technological perspective. The novel patterns presented are primarily based on experiences from practical work on the development of a conceptual dwelling of the future, *comHOME*, designed and constructed as a full-scale model of a flat. By creating different zones for video-mediated communication, *comZONES*, the user can control the private and public digital areas varying in time and space. The novel patterns refer to two separate levels. On the first level a specific pattern, called "PRIVATE AND PUBLIC DIGITAL SPACES", is designed as a conceptual floor plan layout. This plan distributes private and public digital spaces for video-mediated communication over the flat. At a second level, four patterns show the integration of the specific comZONES aiming at solving four specific problems with video-mediated communication at home. Our intention is to describe the application of design patterns as a method for analysing and solving novel problems encountered with the introduction of information and communication technologies in our homes. The video-mediated set-ups are not dealt with in depth. They serve mainly as designs that make it possible to apply the design patterns.

1. Background

We are now experiencing a transition from the industrial society to the society of information. The information and communication technologies (ICT) are the prerequisites for the current transformation from a society based on the production of

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goods to a society characterized by information processing and communication (Dahlbom, 1997). One emerging consequence regards the way we will use our homes in the future. Increasing interdependence in both time and space between work, shopping and traditional domestic activities is assumed to take place (Junestrand & Tollmar, 1998). Further, ICT are assumed to support new processes in the home, thereby overcoming the traditional organization of domestic activities. Many of these processes have a public or semi-public aspect, especially those possibly supported by video-mediated communication (VMC), but to a large extent the existing building stock seems to lack the qualities needed to support those processes. The earlier "public" character of a traditional farmer's house or bourgeois flat has disappeared with the modern housing planning. Instead, distinguishing the public from the private has become central during the industrial age, with the dwelling as a private place. Now, with the transition to an information society, it seems as if the concept of public space in the private dwelling has to be reconsidered (Junestrand & Tollmar, 1998), which means that the border between the private and the public at home is opened up (Graham & Marvin, 1996).

1.1. VIDEO-MEDIATED COMMUNICATION IN THE DOMESTIC ENVIRONMENT

Our core hypothesis is that video-mediated communication (VMC) is useful for the mixed demand required at domestic communication. VMC supports primarily social and emotional aspects of communication, which then become the primary requirements for a VMC system (Kraut & Fish, 1997; Whittaker, 1995). Thus, VMC can support and complement a wide range of home-based activities like, e.g. work, studies, care of elderly and disabled persons, leisure activities and consultations with a bank or a doctor. But VMC, with its current solutions mainly developed for traditional offices, does not seem to be well suited for homes. Other problems are acoustics and light conditions, floor plans and spatial design in general as well as lack of technical infrastructure in existing dwellings. Though, VMC has the potential to open up our homes with new public areas electronically accessible from anywhere and at any time. The main focus of this paper is how to handle the public and private aspects with the introduction of video communication in the domestic spaces.

1.2. THE HOME OF THE FUTURE—A MULTIDISCIPLINARY DESIGN PROBLEM

The design of the built environment of the future is a multidisciplinary activity and requires a variety of competencies, e.g. architects, mechanical engineers, electrical/lighting engineers, telecommunication designers and construction managers (Hartkopf *et al.*, 1999). Emerging problems in the design process of residential houses are the increased importance of ICT competencies and the speed of the development in the field. Another problem is that the change of home-based activities and their organization in time and space is not fully understood by those involved in the design process. The expertise involved, including the architect, seems to adapt to standard solutions without any concern for the new requirements. Pemberton and Griffiths (1998) write: "Clearly it would make sense if, rather than each profession conceptualising the problem and the solution in its own way, they shared some terms and mental structures for communication and design goals and constrains which apply in each area. Buildings

need to be designed by people capable of speaking a common language." Christopher Alexander introduced such a language in the 1970s as *A Pattern Language*.

Pemberton and Griffiths (1998) argue that the various generally available design processes can be effectively applied also to architectural and engineering design from the 1960s and onwards in the US and Europe. In particular, in the complex multidisciplinary domain of building design, they see a place for *A Pattern Language*. Although Alexander's design patterns were originally developed for the domains of architecture, town planning and interior design, they have been applied successfully over the last few years in computer science, e.g. in object-oriented design. Thus, the approach of using Design Patterns as a method for solving multidisciplinary design problems in a variety of fields has encouraged us to develop new patterns for the design of the future home environment.

2. A pattern language as a design methodology

The work of Alexander during the 1970s on the development of a *pattern language* (PL), emerged from a desire to explore the unmeasurable aspects of architecture, which largely had disappeared in modern planning and building during the 1950s and 1960s. This work resulted in two volumes. *The Timeless Way of Building* (Alexander, 1979) contains a description of the making of towns and buildings. Here Alexander intended to show that towns and buildings will not come alive unless all members of a society make them come alive by means of a PL. The book can be described as a theory of PL. His work provides a valuable theoretical framework that is necessary for the understanding of the concept of PL. In *A Pattern Language* (Alexander, Ishikowa & Silverstein, 1977), an applicable PL is presented. The PL has the structure of a network. "The elements of this language are entities called patterns. Each pattern describes a problem which occurs over and over again in our built environment, and then describes a core solution to that problem, in such a way that you can use this solution a million times over, and without ever doing the same way twice." (Alexander *et al.*, 1977). A *core solution*, a notion used by Alexander, is a *generic solution* in terms of systems theory.

"The patterns are ordered, beginning with the very largest, for regions and towns, then working through neighbourhoods, clusters of buildings, buildings, rooms and alcoves, ending finally with details and constructions. This order, which is presented as a straight linear sequence, is essential for the way the language works" (Alexander *et al.*, 1977). Most important is the hierarchical connectivity between the patterns on different levels, which relate them to each other, like a semantic tree representing a total structure.

Alexander *et al.* (1977) writes that "the patterns are very much alive and envolving. In fact, if you like, each pattern may be looked upon as a hypothesis like one of the hypotheses of science. In this sense, each pattern represents our current best guess as to what arrangement of the physical environment will work to solve the problem presented. The empirical questions centre around the problem—does it occur and is it felt in the way we describe it?—and the solution—does the arrangement we proposed in fact resolve the problem? And the asterisk represents our degree of faith in these hypotheses. But no matter what the asterisks say, the patterns are still hypotheses, and are therefore all tentative, all free to envolve under the impact of new experience and observation". This quote explains our own approach to the use of patterns. The PL has been an object for criticism, e.g. its top-down problem-solving principle. Despite this we have found it reasonable to apply PL

TABLE 1
Table of the design pattern structure

Concept	Form	Description
Title	Pattern no. and Text and 0–2 asterisks	Indicates the design solution of the pattern. The asterisks indicate the validity of the pattern, two at most
Picture	Photo or illustration	An archetypal example of the pattern
Introduction	...Text	The context for the pattern by means of links to larger patterns. Starts with three dots
Diamonds	◇ ◇ ◇	Three diamonds mark the beginning of the problem
Headline	Text in bold type	The essence of the problem in one or two sentences
Body of problem	Text and illustrations	The empirical background to the pattern, the evidence for its validity, the range of manifestation in a building and so on
Solution	Text in bold type	The field of physical and social relationships which are required to solve the stated problem in the stated context. The solution is always stated in the form of an instruction so that you know exactly what you need to do to build the pattern
Diagram	Drawing and text	The solution, in the form of a diagram, with labels that indicate its main components
Diamonds	◇ ◇ ◇	Three diamonds to show that the main body of the pattern is finished
Connections	Text ...	Tie the pattern to all the smaller patterns that are needed to complete this pattern. Ends with three dots

as a design method with regard to the home environment in connection with new communication media in the homes, since it offers a scheme that demonstrates and communicates the ideas and experiences we have acquired in our own work.

A design pattern has the following structure (Table 1) (Alexander *et al.*, 1977; Pemberton & Griffiths, 1998) (see Appendix 1 as an example). Later in this paper precisely this structure will be applied to the new patterns introduced for the handling of new VMC technologies in the home setting.

3. Some theoretical aspects

Several fields of knowledge influence our perspective: the architectural, the technological and the social, each with its own framework of concepts and theories. All these fields include an aspect of exploration and design, which we have taken as our common view for the above-mentioned scientific fields. A source for this approach is the "Sciences of the Artificial" by Herbert Simon (Simon, 1981) and further developed by Bo Dahlbom in the 1990s (Dahlbom, 1997). Thus, PL should be seen as a design method rather than as a formal theory.

3.1. DESIGN THEORY

According to Simon (1981), the design process, contrary to the natural sciences, aims to define how things *ought to be*, rather than how things *are*. This leads to Simon's four

criteria for the sciences of the artificial.

- Artificial things are synthesized by man (like our homes, communication systems and devices).
- Artificial things may imitate the appearance of natural things, but lack in one or several respects the reality of the latter (an image of a man on a screen is *not* the man himself, although we may neglect this fact under some circumstances).
- Artificial things can be characterized in terms of functions, goals and adaptation (e.g. a VMC communication shall convey messages, intentions and emotions more fully than a telephone communication).
- Artificial things are discussed, particularly when they are being designed, in terms of imperatives (shall, ought to) as well as descriptives (is, will become).

Dahlbom criticizes Simon, not for the approach, but for not bravely fulfilling the line he initiated. Dahlbom stresses the fact that we live in a world of artefacts that both enable us in different respects and influence our lives. The research on artefacts is oriented towards the future. The research methodology, Dahlbom argues, is *archaeology of the future*. While the archaeologist creates a picture of the past by searching for fragments from earlier cultures and synthesizing and interpolating these fragments, the scientist of the artificial makes designs (fragments of the future), to model and simulate possible larger parts of the future. Dahlbom (1997) writes: "When we realise that the world we live in is an artificial world, a world of human creation, made up of artefacts of all kinds, becoming even more complex and intertwined, our attention will shift from studying nature to contributing to the design of artefacts. In this future science we become, as designers, a part of the design." Thus, our intention is to investigate what is possible in design and thereafter to structure, analyse and communicate our findings.

The idea of design as a science of the future complements other approaches to design as a scientific field. Adrian Forty (1986), e.g. is basically descriptive in his work with unveiling the close connection between the design of objects for the home during two centuries and the concurrent development of society. We also believe in such a connection in our time, albeit not in focus for our work described here.

3.2. SOCIAL LIFE AND EVERYDAY TECHNOLOGY IN THE HOME

In predictions about the future, the domains of work and play, education and entertainment, industry and art, public and private, are no longer strictly separated (Philips, 1996). Transactions and communications continue around the world at the same pace, day and night. At home, too, many activities are performed simultaneously; cooking while watching TV, monitoring the children sleeping in the bedroom while entertaining friends in the living room; working while listening to music, etc. (Venkatesh, 1996).

Hughes, O'Brien and Rodden (1998) describes a more holistic view of the role of technology in the home environment mainly from a sociological point of view. The authors argue that the impact of new technology in the home environment is increasing. They found that the presence of technology in the home is absorbed so completely into the routines of home life that it becomes yet another way in which these routines can be articulated. However, technology is not applied without problems in everyday life. On the contrary, the context of home activities is generally strict. The activities are

constrained by explicit or tacit rules. If reconfigurations of rooms occur, they are carried out within given boundaries. The authors also found, in cases where technology was the reason for the rearrangement, that this caused stress. The technology was badly designed and not user-friendly.

3.3. ARCHITECTURAL DESIGN

Architectural design issues are related to the explorative and creative development of the early functionalist period of architecture with the development of novel ideas for the dwelling occurring in the beginning of this century. The building was then referred to "as a machine to live in" (Le Corbusier, 1986, orig. 1923). Here it is considered more as the central place in peoples' emotional and social lives. There is also a reference to the more formal aspects of architectural design as far as cognitive and psychological aspects are concerned (cf. Hall, 1966; Weber, 1995).

During the planning and design of a dwelling, different spaces might be considered as being more or less private. For instance, the bedroom is considered as private space and the living room might be considered semi-public. But the actual use of these spaces is very different. It unveils e.g. that a bedroom during a party can become a public space with people sitting on the bed or dancing on the floor; or a living room becomes a "bedroom" for an invited guest sleeping in the sofa. Based on the facts that no room has a degree of privacy as a specific property, but is rather decided by how that space is used, we have tried to create designs that can vary in time and space adapting them to the current social context.

Architectural research and development (R&D) related to the use of IT in the home environment, intelligent buildings or smart homes, appear to be focused on technology rather than on architectural design. An exception is the work by Olindo Caso (Caso & Tacken, 1993), which is an analysis and a classification of different IT-supported activities to be carried out in the home environment. The study includes no experimental verifications but gives a comprehensive overview of some of the principal questions discussed here.

3.4. COMPUTER SUPPORTED COOPERATIVE WORK (CSCW)

Within the research area of CSCW, the importance of a medium that might support informal communication has been discussed for long (Kraut & Fish, 1997). Studies of video communication have indicated that the predominant contribution of the video medium is the rich social context (Tang & Isaak, 1993) and that video communication is well suited for informal communication (Bly, Harrison & Irwin, 1993).

We assume that informal network building and maintenance will become even more crucial for the individual when an increasing part of professional work will be carried out at home. Consequently, our working hypothesis is that VMC has the potential to become a major communication media for work at home.

As VMC moves from the office to the domestic environment, we should be able to learn many important lessons from the CSCW research. In the context of video communication for remote collaboration, the major focus has been on whether or not the video

medium actually improves conversation. A great deal of work in this field has moved along the path of defining variables that might be used in order to solve the question of how valuable the video medium really is. In some cases, researchers have been able to separate variables moving along deterministic paths. However, it has been difficult to generalize these findings (Whittaker, 1995). In current research on mediaspace, non-quantitative studies have been conducted in an attempt to specify users' perception and awareness of the presence of others. This provides a new direction to study video communication, by assessing the user experience of the technology rather than by defining some "objective efficiency" factors.

4. ComHOME—a vision of a flat of the future

Our primary research site is the *comHOME* flat, which simulates a dwelling of the future. The site is used both as a laboratory and as a showroom. The comHOME project covers several aspects of a future dwelling. The main goal of the comHOME project has been to integrate VMC solutions into the home, but we work on smart homes too. *Smart* in this context refers to an object or an environment that contains one or more of the following characteristics.

- *Interactive*, i.e. the user can interact with the device and influence the way it works.
- Provided with *information and communication technology*, e.g. sensors, processors and software.
- *Communicable*, e.g. that messages between the user and the device/system can be conveyed and exchanged.
- Set-up with *novel types of interfaces* such as speech, gestures, positioning and touch that differ from traditional ones (screens, keyboards and mice).
- A*daptive* to individual needs and desires.
- *Learning*, i.e. to learn and support the user's habits automatically.

We had the responsibility for the architectural and technological design of the comHOME dwelling. The project was conducted in cooperation with a telecom operator and a company providing and developing Lon-Works automation technology.

The comHOME dwelling consists of three rooms: a living room, a kitchen, a combined home office and bedroom. It was constructed as a full-scale model inside an existing office building. It is not a complete flat; for example, there is no bathroom, and the floor-plan layout is not intended to live in.

In our attempt to explore the usability of the concepts *private and public digital spaces*, we have designed a set of four places, *com*ZONES, for which we have created different architectural and technical design set-ups. Each one of these set-ups is independent and aims at supporting fundamental home-based activities. This has forced us to work with the core processes of every activity. However, in real life the whole dwelling should be seen as a potential place for e.g. "telework", rather than having this activity strictly limited to a specific area (Junestrand & Leal, 1998).

The comHOME flat was built on the basis of existing "on the shelf" technologies. The presentation of the new design patterns below describes a mix of what has been done and visions of what is going to be done in the near future in the design of the comHOME flat. The solutions of the different comZONES will not be further described here [for more

detailed descriptions, see Junestrand, Tollmar, Lenman & Thuresson (2000) and Junestrand & Tollmar (1999)].

5. Our task

The research project aims to *explore* and to *make proposals* for new patterns when using ICT in the home. The general research objective is: "how should VMC solutions be designed and integrated into a future home environment, with regard to the need for both private and public spaces in the home?"

From this starting point, more specific research objectives can be formulated. As mentioned earlier, the questions can be referred to two levels. The first level refers to the whole floor plan layout of the dwelling.

- What should a general floor plan pattern look like in a home of the future, when integrating digital public and private spaces?

The second level addresses the VMC solutions proposed or designed.

- How should the different design patterns be formulated in order to generalise the experiences of the specific comZONES, set-ups, developed for the comHOME?

Some general background questions have guided our work.

- What processes in the home environment of everyday activities of the future can and should be supported by VMC?
- How should the specific VMC set-ups be designed to support the activities they are supposed to support?
- What is the organization of time and space for everyday activities like in a future home environment?
- How can VMC be integrated with other advanced domestic technologies and a general smart system?
- How can the design pattern methodology contribute to the formulation of requirements for new interfaces, in order to facilitate user interaction with the VMC system?

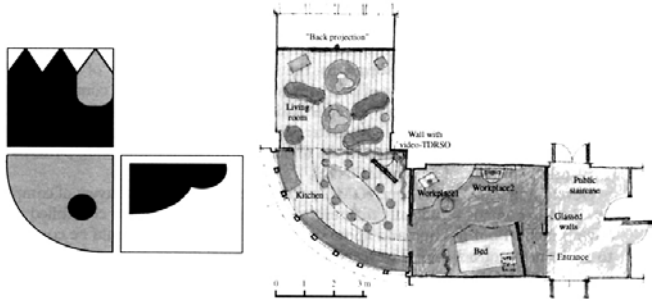
Below, we elaborate some of these questions, by applying the pattern language methodology. In a way, this is an intellectual exercise, aiming at the exploration of PL. Further, our aim is to contribute a better insight into the crucial issue of public and private spaces, and into the VMC and its constraints.

As pointed out above, many restrictions have to be considered when the result from the analysis is interpreted. Communication of other sensations than image and sound, such as tactile communication, smell and taste, are not supposed to take place, although such qualities will certainly not be excluded in the long term. We are also limiting ourselves to images on screens and, in one case, a back projection. Furthermore, several activities could certainly have locations better suited for a part of the living process than those arranged for and described here. Reading a book on a sofa, for example is more natural than sitting with a book in front of a VDU. Also, only fixed set-ups are tested and no mobile unit has been used due to technological limitations. The work described here is primarily a test of *A Pattern Language* (Alexander *et al.*, 1977) as a method of design and communication, rather than a test of specific set-ups. So, the PL has not been applied to the design of the set-ups, rather it is tried in order to explore if it is a convenient method for the design of other set-ups.

6. Design patterns for private and public digital spaces in the home environment

A set of new patterns, developed from the comHOME flat, is presented in this section. The patterns strictly follow *A Pattern Language* presented by Alexander (1977), see Table 1 for the applied schema and Appendix 1 as a reference to an original pattern. The number given to each new pattern is chosen so that we can introduce our new patterns in the context of an existing pattern language. From the perspective of the design of a home, the patterns represent two structural levels. On the first level there is a general pattern "PRIVATE AND PUBLIC DIGITAL SPACES" for a flat, which is shaped as a grid over a conceptual flat floor plan and which distributes private and public (fixed and flexible) spaces for video-mediated communication (VMC). On the second level, there are a number of patterns that provide solutions for the integration of the specific comZONES (communicative zones for VMC) that support different home activities, and where the resident can be seen and heard in different ways varying in time and space. The comZONES are described principally from an architectural perspective (representing form and function) and a technological perspective (hardware and software). Note, however, that the descriptions of the comZONES in the proposed patterns are a combination of existing technologies on the one hand, and on the other, design concepts and goals that are not yet fully in use.

6.1. (127 b) PRIVATE AND PUBLIC DIGITAL SPACES



To the left: *Conceptual design of the floor plan indicating the comZONES. In the inner black zone the individual can be both seen and heard by the VMC equipment. In the outer grey zone the resident may only be seen but not heard. In the surrounding white zone the person can neither be seen nor heard. The zones do vary in time and space.* To the right: *Floor plan sketch of the dwelling. The entrance is at the lower right. The middle room at the bottom is a combined telework and sleeping room. To the lower left is a kitchen, and to the upper left is a living room.*

...The current development of information technologies is rapid and VMC will probably become an important part of the communication to and from our homes in the future. VMC has partly a public character. This pattern helps to distribute the integration of private and public digital spaces in the design of the dwelling. It is also connected to THE FAMILY (75), the HOUSE FOR A SMALL FAMILY (76) and the HOUSE FOR A COUPLE (77). It also refers to the MAIN ENTRANCE (110) and complements (and in some way opposes) the INTIMACY GRADIENT (127).

◇ ◇ ◇

New public digital spaces are created when activities supported by video-mediated communication are performed throughout the domestic environment. This breaks the established hierarchical separation of private and public spaces in the design of the home. If the different aspects of this problem are not addressed consciously a lot of people will feel uncomfortable and insecure in their own home.

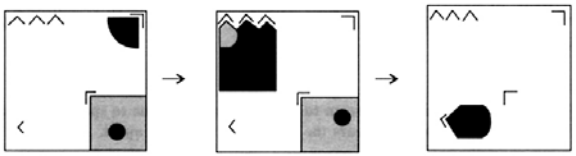
The spatial design of comHOME supports activities with the use of VMC and is based on the idea of creating different comZONES (zones for video-mediated communication) in order to support the demands of both private and public digital spaces in the home. In *public zones*, a person can be both seen and heard with the help of an image and a sound recorder (VMC). In *semi-public zones*, the individual can be seen but not heard. In the *private zones*, the resident can neither be seen nor heard. The zones are variable in time and space.

The governing architectural principle of the design of the comHOME flat was to establish mental and physical boundaries between the public and the private zones. A good balance between the VMC-activities and other everyday activities is important. Both the inside-out and the outside-in perspectives were acknowledged, i.e. how the outside is perceived through VMC from the inside, and how the inside is perceived from the outside. This was solved by the creation of a number of comZONES intended to support a number of everyday activities. The different comZONES are expressed by technical set-ups—screens and cameras—and by using architectural terms—spatial forms, colours, light, materials. Thus, the architectural space related to ICT solutions forms an interface to the digital world (see the following patterns for descriptions of each of the comZONES).

Developing VMC in the comHOME setting uncovered multiple layers of complexity. First, a home is a radically different place compared to a more controlled office environment. Poor lighting and audio conditions, for instance, should be considered to be the norm rather than the exception. The technical design of the video and audio space in comHOME is based on several short-range cameras and microphones that are mapped and routed through a common media switch. The switch could be seen as the heart of all incoming and outgoing media streams. The control of the media switch is monitored either via a remote control or via a graphics user interface, or, automatically, by the central logic of the smart home. Further, a default set-up could be activated by the central logic of the smart home that governs the data stream through the media switch. Hence, the video and audio space is closely linked to the automation of comHOME as a smart home. An incoming video call, for instance, could automatically be routed to the room where the receiver is and triggers dimming of the lights and muting of the radio in the room.

The different comZONES for the rooms in comHOME can be created in many different ways. Reducing the number of potential solutions is a major undertaking. With the location of the cameras, the control of depth of field, and viewing angles, the video space in the different zones could be adjusted. The control of the audio space is more crucial. Array microphones and spatially directed loudspeakers might be a solution. However, experience of these technologies was lacking. Similarly, real-time image manipulation, which extracts irrelevant background activities, can be used in some cases. Early works have proposed the use of physical metaphors for the control of the video and audio space in VMC systems. One approach, suggested by Kawai, Bannai and Tamura (1996), was to use a graphics user interface with a floor plan in order to control the viewing range of the cameras. Most of these methods suggest an explicit and direct control of the cameras. For comHOME, the variation of the zones in space will mainly be controlled by a spatial recognition system linking the physical position to the identity of the person(s) in the room.
Therefore:

Design and locate the comZONES in the dwelling in such a way that they support the activities they are designed for in the best way possible. At the same time the design and locations of the comZONES have to be integrated so that they do not interfere with other everyday activities. The comZONES should be expressed both in the architecture and technology and made to fit naturally into the home environment. The public places may vary in time and space but it should always be clearly indicated whether the comZONES are in a communicative mode or not, i.e. if the space is *public* at the moment. This should be done by a clear feedback to the user (similar to WYSIWYG—what you see [and hear] is what you get, but with an extended and entirely new interpretation). This will make people feel comfortable and secure in the home environment.



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Consider the possibility to use INDOOR SUNLIGHT (128) for some comZONES and create comZONES in relation to COMMON AREAS AT THE HEART (129). To complete the pattern, consider A ROOM OF ONE'S OWN (141), a good

distribution of SEQUENCE OF SITTING SPACES (142) and that the STRUCTURE FOLLOWS SOCIAL SPACES (205)...

6.2. (196b) VIDEOTORSO

...A desire for more informal social contacts with friends and members of the family can be fulfilled with the help of a videoTORSO, which is a set-up enabling communication with a person as if he/she stood in the room. This pattern helps to complete the aspect of informal social communication in PRIVATE AND PUBLIC SPACES (127 b), COMMON AREAS AT THE HEART (129) and at the FARMHOUSE KITCHEN (139), and makes the pattern design applicable to the home context.

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Family members and friends seem to have less and less time to spend with each other. The lack of communication tears the family and relations apart.

Informal social communication between family members and friends is crucial to personal relations. But individuals, both within the family and among friends, seem to spend less time in each other's company. This concerns both the number of times people meet and the length of time they spend together. The physical distances between related persons also increase because of the fact that people travel more and longer distances and that the patterns of human habitat are more widely spread around the world, for both social and economic reasons. The need for informal social communication in the domestic environment among family members and friends will probably remain strong. The *videoTORSO*, which is a VMC set-up, is intended to support this type of casual conversation style. The hardware and software of the videoTORSO consist of the following.

- A large flat screen placed on a wall, which is possible to adjust in height, thereby allowing for both tall and short standing users.
- Loudspeakers just above each side of the screen, making the sound appear from the videoTORSO.
- A camera with automatic tracking placed as close as possible beside the eye level of the person appearing on the screen.
- Microphones placed just beside the screen.
- Software for video communication, voice and gesture commands.

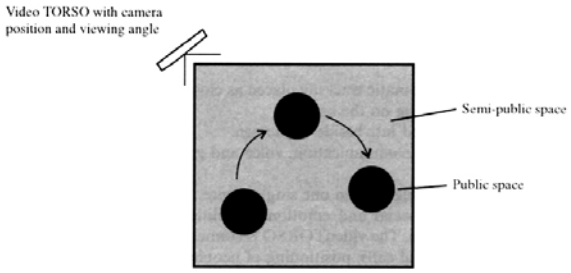
These parts are integrated in one single device, the videoTORSO, which makes it possible to convey social and emotional qualities similar to those that could be attributed to a person. The videoTORSO is connected to the logic of the smart home, and enables routing of calls, positioning of people, etc.

The location of the videoTORSO in the room is also essential. If the objective is to simulate a person standing in the room, it is important to locate it at a place that is natural to turn to. It is also important to consider the tracking cameras connected to the videoTORSO. They capture the person and his background. The limits of the camera view (angles of tracking) have to be controlled. This can be done with architectural delimitations or software/hardware solutions and may restrict the location of the videoTORSO to places where the viewing angles and the background are physically obscured by the architectural design, e.g. a wall or a curtain. The sound in the room should be captured mainly from the person having the conversation. If several persons participate, the sound from all of them should be captured. People in the room who are not participating in the conversation should only appear as images producing background sound and images and are thus *semi-public*.

The videoTORSO might substitute a person in the room. The person at the other side of the screen, however, will not experience him/self being in the kitchen. Since the camera automatically tracks the person in the kitchen, the environment is not fully perceived. This makes the dynamic space around the communicating person a *public space* and the rest of the room becomes at least partly *semi-public* or *private*. It is fundamental that the system's feedback is clearly expressed. When testing the systems, we noticed that people felt that they themselves where not seen or heard as soon as the VMC set-up was black and mute. It is recommended to locate the videoTORSO in a relatively public space, preferably the kitchen, where informal everyday activities usually take place. This provides high accessibility and natural user situations.

Therefore:

Create a videoTORSO, equipped with a large flat screen mounted on a wall, loudspeakers and a camera with tracking functions and microphones, constituting one single entity. Place it in a corner of the room, with the viewing space expressed in the spatial design. The public space should follow the user. The rest of the room has to be considered as semi-public. Locate, if possible, the videoTORSO in the kitchen or another room that is often used for informal everyday communication. This system should be connected to the central logic of the smart home and be provided with an overall design that enables seamless communication of a high quality.



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The FLOOR AND CEILING LAYOUT (210) and NATURAL DOORS AND WINDOWS (221) are crucial to the successful use of the videoTORSO. The design of this pattern is completed and might be improved by considering DEEP REVEALS (223) and the LOW SILL (222)...

6.3. (157b) DIGITAL WORKPLACE

...A workplace for professional work, as a part of OFFICE CONNECTIONS (82), supported by video-mediated communication in domestic environments, must often

be perceived from the outside (by the remote person) as a *public* place. Sometimes, the space that this pattern forms is to be considered as A ROOM OF ONE'S OWN (141), although it should rather be considered as a space than as a room. It is also necessary to make the people at and around the digital workPLACE feel comfortable and *private*, so consider INTIMACY GRADIENT (127), PRIVATE AND PUBLIC SPACES (127 b) and THE FLOW THROUGH ROOMS (131). In some respects, this pattern replaces the HOME WORKSHOP (157), but in other respects it is a complement. If this pattern is used correctly it will be found that the integration of a *public* space into a *private* room works well.

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The use of VMC for professional work activities in a home environment might create many problems, both for the person performing professional work supported by the video-conference system and the persons around the workplace, whose integrity can be

Upper left and right: *the user appears as in the real home environment using the videoconference system.* Lower image: *from the remote place (the perceived image by the partner in the conversation) the user appears to be in an office environment, a process handled by software manipulation of the video image.*

disturbed and who may feel uncomfortable. Therefore, it is important that one is able to feel private and comfortable when passing behind someone using a VMC set-up for professional work.

Professional work supported by ICT at home tends to increase. The working hours seem to be extended around the clock. The globalization, increasing flexibility of working hours and the technology development are some reasons for this development. People tend to locate places for telework to very private spaces such as bedrooms, because of a lack of suitable places at home. This might work well until VMC becomes a more common device for the work. Then it will be necessary to control the areas of the private space around the workplace that can be captured by a videocamera at the desktop. But it will be equally important to be able to feel private and secure when being behind someone using a VMC set-up for professional work.

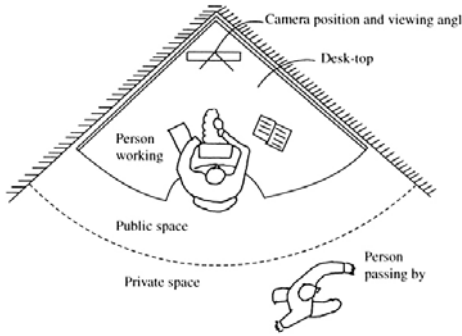
In a set-up developed at the comHOME project, the workPLACE is placed in a combined home-office and bedroom, which causes the camera to view not only the person at work, but the bed behind, as well. This pushes the aspects of private and public to its limits and requires a development of measures that facilitate the interpretation of the borders between *private* and *public spaces*, as well as complementary ICT devices and software. A table with two sideboards and a lowered ceiling with integrated light defines the *public zone* spatially, where the user can be seen and heard. The zone outside, with the bed, is *private*. This is achieved with a short-range microphone that captures only the voice from the person seated at the workPLACE, and with a software for the digital camera that cuts out the person sitting at the workPLACE and places her in the background of an office environment.

The workPLACE only allows for the core activities supported by the VMC and the additional necessary equipment; other functions can be distributed arbitrarily throughout the dwelling. The space has one or several computer screens, with an additional desktop camera as the visual focus of the VMC. The workplace should include a comfortable table area that provides good ergonomic conditions. Besides, the workplace should be extended so that the desktop worker can sit and move freely at the table. The work area—the public area—should be delimited by an architectural design that is easy to understand. The workplace should allow for work to be carried out without the user unintentionally getting outside of the public zone. The area outside the public zone allows for a person to pass comfortably behind the digital zone unseen.

Therefore:

Create a workPLACE with a desk with the space necessary for the performance of core activities, and those supported by the VMC with the necessary equipment. The space should have the focus point at a screen for VMC equipped with a desktop camera. Generate a radius from its approximate position, which indicates the outer limit of the table. Generate another, larger, radius, which delimits the *public zone* and has the same centre as the first radius. The difference in length between the two radii should allow for work to be carried out without the user getting outside of the public zone unintentionally. It should be possible for a person to comfortably pass behind or stay behind the digital space in the area outside the public zone unseen and unheard. Indicate clearly the border between the public and private zones, using architectural design.

The input to the system of images and voices should be strictly limited to the public zone, while the output might be experienced also from the private zone. This problem can be resolved by using, for instance, a headset and limited projection of images in glasses. The figure of the person at the digital workPLACE should be cut out and the background replaced by an image of an office environment or by another convenient background.



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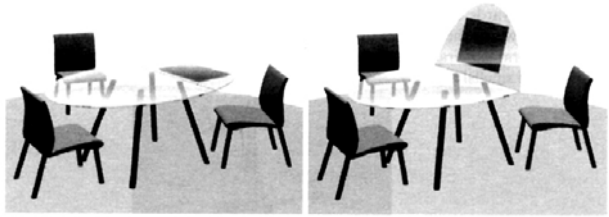
Use the play with TAPESTRY OF LIGHT AND DARK (135), WORKSPACE ENCLOSURE (183) and CEILING HEIGHT VARIETY (190) to complete this pattern ...

6.4. 182b COMTABLE



... This pattern forms a part of a SEQUENCE OF SITTING SPACES (142) among the COMMON AREAS AT THE HEART (129), which is distributed within the grid of PRIVATE AND PUBLIC SPACES (127 b) in the home. It is a fundamental part of the FARMHOUSE KITCHEN (139), COMMUNAL EATING (147) and completes the EATING ATMOSPHERE (182).

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The activity of eating together is important for the unity of the family or a group of closely related individuals, and for the social upbringing of children. Getting together for a meal is often difficult nowadays due to the separation in space of the individuals.

The act of eating together is a cultural activity that is full of rituals and common experiences. Everybody "knows" how to have dinner. So, it is an activity that is best carried out in a shared environment, even if some of the participants are not physically present. An important part of the social upbringing of children takes place at the dinner table. Nowadays, however, it seems to be difficult to get together not only for dinner during the weekdays, but even for the traditional Sunday dinner. Parents may work too much and at irregular hours, children may study elsewhere, grandparents and other relatives may live in other parts of the country, etc. The *comTABLE* offers a complement to the physical participation of a person being at a remote place, who otherwise would not have been able to attend at all. The comTABLE contains a flat screen, a camera, microphones and loudspeakers, which are integrated into a mobile frame at one end of a dinner table. This arrangement permits everybody around the table to perceive the image and it reproduces the remote person in a fairly natural size and position. The screen can be folded and hidden in the table when not in use. It is just as easy to use the table without the video communication.

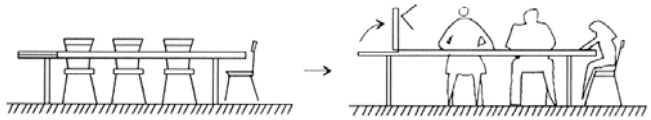
If a remote person connects with the table, he/she appears on the screen, but will not hear or see anything. When the frame is lifted and put in a vertical position the system connects the input devices to the guest and the person can hear and see what is going on at the table and participate in the dinner conversation. After dinner, the screen being folded down terminates the communication, and thereby the flow of information is discontinued. By integrating the screen, camera, microphone and loudspeakers into the foldable part of the device, the control of the visual view and sound becomes very physical; as a syntax for adjusting the public and private space of the comZONE. A comTABLE is a substitute for the dinner table and should be placed where this is generally placed. The location of the table should allow for the light to be directed towards the persons around the table. The sun or strong light must not be directed towards the screen. For future designs we can imagine more screens around the table, several cameras and more complex sound-capture—and maybe even the transmission of smells!

The remote dinner guest appears on the screen, still without seeing or hearing anything, when down...

...and is invited to the dinner by the lifting up of the screen.

Therefore:

A comTABLE should have an integrated screen that permits a person at a remote place to participate in the dinner. The participation of the person on the screen should be easy to control (cf. opening the front door for a guest). Therefore, the screen, camera, microphones and loudspeakers should be integrated in foldable frame. When the equipment is directed towards the ceiling, the remote person cannot see or hear anything. The screen should be placed in the rear end of the table, which permits the best view for the persons around the table as well as the person on the screen.



As a normal dinner table

With the screen folded up for a dinner with a digital guest

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Use POOLS OF LIGHT (252) to produce lighting that both supports the activity of eating and improves image quality for the remote dinner guest ...

6.5. 147b MEDIASPACE

...This pattern supports the social interaction between THE FAMILY (75) and family members and friends at remote places. It should be considered as the most public space within the INTIMACY GRADIENTS (127) and should be treated as one of the COMMON AREAS AT THE HEART (129) that are distributed within the grid of PRIVATE AND PUBLIC SPACES (127 b) in the home.

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Social and cultural events such as parties, weddings, anniversaries, celebrations, etc., are examples of a cultural heritage that should be kept alive. Ordinary everyday activities are more stimulating to carry out in the presence of other family members or friends than by oneself. Nowadays, however, family members and friends live further away than before. It is often impossible for many members of a family or a group of friends to attend both everyday activities and special social events. This might create isolation and tear relations apart.

People move around the world for work and for leisure more than before. Friends and families often live far away, in distant regions and other countries. Many social activities have taken place without the possibility for everyone concerned to attend. The mediaSPACE is a digital social space both for formal and informal events.

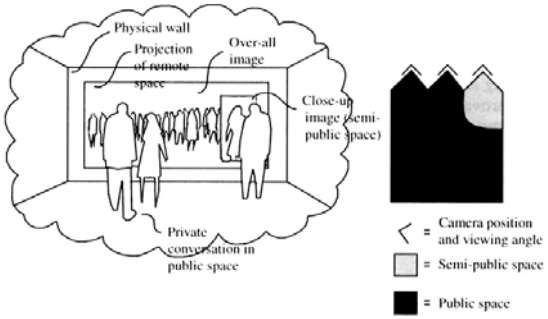
The participation at a wedding, maybe on the other side of the world, celebrating with the just married ... and then having a private talk.

At anniversaries, weddings, christenings and parties, etc., it is important to get an overview of the space occupied by the participants. But it is equally important to create the possibility of a focused view of a specific individual or a smaller group of people. Thus, the mediaSPACE contains a large wall with a general overview projection of the whole space, and provides a possibility to get a picture on a part of the screen, similar to a "window" covering a part of the background. The cameras are located at the media wall in order to generate viewing angles that are as natural as possible over the space. The sound system can be connected to the surrounding system of the space. The microphones are placed at the media wall in order to capture the general atmosphere of the sound, and to create possibilities for private discussions

on the other hand. The user must, of course, be aware of this arrangement in order to carry out a more *private* conversation within the public space.

Therefore:

Create a system that is able to generate a large digital social space. It consists of a wall exposing wide landscape images, cameras to capture both overall images and close-ups, and microphones to capture both the overall sound and sounds from specific locations in the room. This can be done by placing a pictorial cutout of a person or a smaller group within the framework of the large image, close to the border to the large screen. It should be possible to get closer to the wall and have a more private talk with a remote person or a smaller group of people. This procedure has to be supported by the sound system, which must create a general background sound as well as specific directed sound for personal conversation. The system has to be supported by at least one camera for an overall image. The image projected on the media wall must seem natural. At least one camera is required for the support of the close-ups. The lighting is crucial and must be compatible with the technical design. Good general lighting from above, supported by lateral lighting is preferred. The remote site should have a similar set-up.



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To complete this pattern, consider the INDOOR SUNLIGHT (128), the SITTING CIRCLE (185) and THE SHAPE OF INDOOR SPACE (191), as well as the possibility to use WARM COLORS (250)…

7. Discussion

The examples above demonstrate how Alexander's PL might be applied in a specific setting and with a specific technical artefact, i.e. the home setting and VMC. The patterns have been designed on the basis of the experiments conducted and the designs developed

for the comHOME project. During the R&D on comHOME and its patterns it has become apparent that a surprisingly large number of the aspects of the various comZONES seem to be possible to generalize in order to support different aspects of video-mediated communication in the home environment.

Although the setting for this exercise is confined to a specific set-up, comHOME, it offers a possibility to test the principles of *A Pattern Language* according to Alexander. The very nature of PL is explorative—it permits the development of new patterns based on hypotheses that have not been absolutely verified.

The following specific issues could also be mentioned.

- We are aware of the fact that our new patterns are not fully compatible with Christopher Alexander's *A Pattern Language* of 1977. By further adapting our patterns to his schema in order to get a description that is as complete as possible, we will get a better insight into the nature of our particular problem, in particular with respect to how the conflicts between new media at home are influenced by traditional floor plans. What architectural and technical measures could be taken in order to reduce these conflicts and how could we benefit from the challenges they offer?
- The work on *A Pattern Language* has encouraged further development in the area of intelligent buildings and smart homes. It seems, but still remains to be proved, that the pattern language is a point of departure for a more precise definition of a schema that could lead to results that are clearer and can be used more directly.
- Several design methods should be considered for the work to develop new patterns. To design by creating *scenarios*, e.g. by making a movie (Junestrand *et al.*, 2000), by performing *user studies* (with intellectually disabled persons) and through *workshops* have all proved to be productive methods. They have also helped us to keep the designs close to systems supporting basic aspects of everyday life which ordinary people can use.

To us it seems that the scientific approach in all essential respects underpins the methodology that we have used in the practical experiments. This is important and should be considered also for future progress of our work.

8. Future work

The work on the development of design ideas for the comHOME flat is carried out continuously. A user study with a number of intellectually disabled and non-disabled persons was carried out in comHOME in the summer of 1999. This study is now being structured and analysed. Furthermore, an experimental video with professional actors demonstrating the different VMC set-ups in the social context of everyday life was recently recorded in comHOME (Junestrand *et al.*, 2000) and it is used as a basis for supportive discussions about the work. Improvements and redesigns of the comZONES are under way, as well as a further integration of the VMC with a smart environment system that now functions separately.

The principles of the patterns presented in this paper can be introduced in real flats. A housing company will, in collaboration with us, apply these principles to a multistorey residential building in southern Sweden, in connection with a housing fair during the year 2001.

The work on the comHOME flat was conducted in collaboration with S-lab at Telia Networks in Farsta, Stockholm, to whom we are deeply grateful. We would like to mention Roland Bohman and Lasse Lindblad at this lab. We would also like to mention professor Yngve Sundblad, director of the Centre for User Oriented IT-design at KTH, and professor Ingvar Sjöberg, director of the Smart Things and Environments for Art and Daily Life Group at the Interactive Institute, for their support throughout the project. The Swedish Council for Building Research supported the research on IT Supported Services Infrastructures in the Built Environment at the School of Architecture at KTH, which is fully acknowledged.

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Appendix 1. PATTERN 184, COOKING LAYOUT

From *A Pattern Language*, Alexander *et al.*, 1977. Copyright by Christopher Alexander 1977. Used by permission of Oxford University Press, Inc.

... within the FARMHOUSE KITCHEN (139), or any other kind of kitchen, it is essential that the cooking area be fashioned as a workshop for the preparation of food, and not as

some kind of magazine kitchen with built-in counters and decorator colours. This down-to-earth and working character of a good kitchen comes in large part from the arrangement of the stove and food and counter.

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Cooking is uncomfortable if the kitchen counter is too short and also if it is too long.

Efficiency kitchens never live up to their name. They are based on the notion that the best arrangement is one that saves the most steps; and this has led to tiny, compact kitchens. These compact layouts do save steps, but they usually do not have enough counter space. Preparing dinner for a family is a complex operation; several things must go on at once, and this calls for the simulataneous use of counter space for different projects. If there isn't enough counter space, then the ingredients and utenils for one thing must be moved, washed, or put away before the next thing can be prepared; or else things become so jumbled that extra time and effort must be taken to find what's needed at the proper moment. On the other hand, if the counter is too long or too spread out, the various points along its length are too far apart—and cooking is again uncomfortable, because your movements as you cook are so inefficient and slow.

Empirical support for the notion that there is insufficient counter space in many kitchens comes from a recent work by the Small Homes Council, University of Illinois. The Council found that in over a hundred housing developments, 67 per cent had too little counter space. No one complained that their kitchens were too large.

In *The Owner Built Home* (Yellow Springs, Ohio, 1961, Vol. IV, P. 30), Ken Kern notes that a principal concept in cooking design is to provide for storage and workspace at each of the major cooking centers in the kitchen. Drawing on a Cornell University study he identifies the major cooking centers as the sink, the stove, the refrigerator, the mixing and the serving areas. To provide storage for each center requires 12 to 15 feet of free counter space, excluding the sink, drainboards, and stove. (*The Cornell Kitchen*, Glenn Beyer, Cornell University, 1952.)

A kitchen that really works: huge, but great.

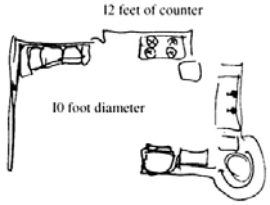
As far as the limits on the distance between these major cooking centres are concerned, there is less empirical evidence. Estimates vary. The rule of thumb we postulate is that no two of them should be more than three or four steps, or about 10 feet, apart.

Therefore:

To strike the balance between the kitchen which is too small, and the kitchen which is too spread out, place the stove, sink, and food storage and counter in such a way that.

1. **No two of the four are more than 10 ft apart.**
2. **The total length of counter—excluding sink, stove and refrigerator—is at least 12 ft long.**
3. **No one section of the counter is less than 4 ft long.**

There is no need for the counter to be continuous or entirely "built-in" as it is in many modern kitchens—it can even consist of free-standing tables or counter tops. Only the three functional relationships described above are critical.



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Place the most important part of the working surface in the sunlight—SUNNY COUNTER (199); put all the kitchen tools and plates and saucepans and nonperishable food around the walls, one deep, so all of it is visible, and all of it directly open to reach-THICK WALLS (197), OPEN SHELVES (200). . . .