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Author(s)	Dalton, Cathy
Publication date	2014
Original citation	Dalton, C. A. 2014. MyRoom: A user-centred model of affective responsive architecture. PhD Thesis, University College Cork.
Type of publication	Doctoral thesis
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MyRoom:

A user-centred model of affective responsive architecture

Doctoral Thesis submitted to University College Cork

by

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Cork Centre for Architectural Education, UCC/CIT

Head of Department: Professor Kevin McCartney

Supervisors: Dr. James Harrison, Prof. Kevin McCartney

‘We shape our buildings, and afterwards our buildings shape us’

-Winston Churchill

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Declaration

I declare that this thesis is my own work, and has not been submitted for any other degree, at University College Cork or elsewhere.

Signed

Date



2 January 2014

Cathy Dalton, B Arch MRIA

Acknowledgements

The doctoral research was funded from 2009-2013 by a scholarship and bursary from the NEMBES research cluster, a PRTL-IV project funded by the Higher Education Authority.

My thanks must go firstly to my supervisors at CCAE, Dr. Jim Harrison and Professor Kevin McCartney, the former for encouraging, cajoling, pushing and occasionally dragging me through the long process of producing a doctoral thesis, and the latter for accepting me as a doctoral candidate in the first instance, as well as being instrumental in awarding me the NEMBES bursary and scholarship, without which the research might never have happened.

Particular thanks to Richard Mazuch, Nightingale Associates, whose own research and passionate interest in healthcare design provided the initial spur for my research efforts; also to Dr. Dirk Pesch, CIT (Lead PI, NEMBES project) Dr. John Barrett, CIT (PI, NEMBES) and Dr. Ken Brown, UCC (PI, NEMBES), for guidance in exploring the arcane (to an architect) realms of ICT and sensing. Special thanks to Dr. Samantha Dockray, School of Applied Psychology, UCC, for her collaboration on the MyRoom prototype.

To the many friends who supplied moral support and unending patience throughout, particularly in the final year, most especially Niamh Butler and Valerie Walsh, and my fellow-PhD students James Cussen (UCC) and Jennifer Kavanagh (TCD/WIT), for their wit, wisdom and critical input online and off, and to Dr. Richard Hawtree (UCC), for posing a critical question at a critical juncture, which fundamentally altered the course of the thesis for the better. A special mention is due to Michal Dabski, (DIT), for coding the ShimmerVideo application, and to my research interns, Karen Barrett, Andrew O'Callaghan, and Daniel Waugh, for their assistance with the MyRoom Demonstrator and pilot tests. My thanks also to the broader online community of academics, as well as the many other friends I have made on social media over the last four years, who have followed my academic trials and tribulations, and provided company and support while I worked remotely.

Lastly, thanks to my long-suffering children Philip and Iseult O'Donnell, (both true digital natives) for enduring an often distracted, occasionally absent, and frequently absent-minded parent, especially in the final weeks of writing-up. Normal service will resume shortly.

MyRoom:

A user-centred model of affective responsive architecture

INTRODUCTION

My Wallpaper and I are fighting a battle to the death.....¹

Can my immediate physical environment affect how I feel? The instinctive answer to this question must be a resounding “yes”. How many times have we said to ourselves “if I spend one moment longer....” or “I need a change of scenery?” What might at first glance seem to be throwaway remark is increasingly borne out by research in environmental and behavioural psychology, and in the more recent discipline of Evidence-Based Design. Research outcomes from these disciplines are beginning to converge with other findings in neuroscience and neurophysiology, as we discover more and more about how the human brain and body functions, and how it reacts to environmental stimuli on a constant and ongoing basis. In his seminal book “Survival through Design” (Neutra, 1954), Richard Neutra refers, somewhat presciently, to what is now described as “neuroplasticity” when he says that “The 24-hour-a-day, 365-day-a-year stimulus” of the architectural environment may perhaps “physiologically teach, by moulding the nervous make-up even of an adult”, and even more interestingly, maintains that the designer “deals primarily with the nervous system”, through continuous perception of and reaction the designed environment. What have been categorised, as “gut reactions” are all that and more: what we see, hear, touch, and sense affects each of us psychologically and, by extension, physically, on a continual basis. The physical characteristics of our daily environment have the capacity to profoundly affect all aspects of our functioning, from biological systems to cognitive ability. This has for long been understood on an intuitive basis by many, and utilised on a more conscious basis by architects and other designers who have greater impact on the shaping of human

¹ Attributed to Oscar Wilde on his death-bed in Paris, 1900

environments. Recent research in evidence-based design, coupled with advances in neurophysiology, confirm in some instances what have been previously held as commonalities, but also illuminate an almost frightening potential to do enormous good, or alternatively, terrible harm by virtue of how we choose to make our everyday surroundings. Never does that responsibility on design practitioners come to bear so much as in the arena of healthcare design, where the end-user, who represents the ultimate client, is of her very nature vulnerable.

The thesis adopts a design methodology in its approach to exploring the potential use of wireless sensor networks in environments for elderly people, this specific query being a requirement of the NEMBES² funding for the doctoral research. Having practised as a professional architect for many years, I had arrived at the point where I felt that issues which were of concern, and which arose repeatedly during the design and procurement of healthcare architecture, namely the arguments for quality of design for the benefit of patients and all users, would be better addressed through research. A long-term interest in use of colour in the built environment and its possible effects on wellbeing was also a motivator, in addition to a long track record in designing accessible environments, with an innovative approach firmly rooted in the belief that accessibility, or inclusivity, in the built environment, should be as integral and seamless an aspect of design, and as natural and normal concern for the architect, as, say, daylighting, proportion, use of materials and so on. In consideration of the Vitruvian principles of “commodity, firmness and delight” (Vitruvius), commodity, where it is defined as to ease of use for as broad a section of the population as possible, seems to have almost fallen out of favour as a determinant of what constitutes good design. All of these concerns, born from practice, inform the research process and become embedded in the final design proposals and research conclusions.

² NEMBES was an interdisciplinary, inter-institutional programme funded by PRTL-IV, investigating embedded sensor networks in built environment.

The key research questions, based on a preliminary literature review, are as follows:

- **What are the key system characteristics of an adaptive therapeutic single-room environment?**
- **How can embedded technologies be utilised to maximise the adaptive and therapeutic aspects of an own-room long-stay healthcare environment for an elderly population?**

Methodology: Designerly ways of knowing (Cross, 2007)

“Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research”. –Albert Einstein

For a majority of designers across design disciplines, the idea of academic research is anathema, while at the same time, designers routinely engage in iterative and disciplined thought processes in the production of any piece of design work. Traditional research in both the sciences and humanities tends to isolate, while design synergises, relying on “joined-up thinking”. The value and inherent rigour of design thinking are largely unacknowledged in academia. The designer and the design researcher are rarely the same entity. Traditionally, research tends to isolate, to be specific, while design takes a broad and solution-based approach, which in the real world is the most productive approach. “Design” might be described as the best solution to a specific problem given the available resources and constraints at a given time. It does not produce one single solution. Designerly ways of thinking are spatial rather than linear. What is commonly referred to as “intuition” is but a term for a particular way of thinking, rather than some mysterious form of divination, though it is still often scoffed at by those outside creative disciplines and professions. At this point in time there is a body of academic research into the design process, and creative cognition. Nigel Cross

likens the design process as less one of making a sudden “creative leap” than building a “creative bridge” between the problem and the solution.

Though the thesis is largely written, it still takes the solution-based approach of any piece of design work, with iteration featuring strongly. The original concept, which formed part of the research proposal at the very outset, remains intact throughout, though it becomes progressively more and more refined, and detailed, with each iteration. This methodology, which takes the form of a problem-solving approach to the research question, is supported by the position that design, as a research discipline, has its own rules and its own methods of discovery of knowledge. In this case, it has not been possible to produce a built outcome or even a full design, as the technologies required to support such an eventuality are still embryonic, and such an endeavour will require cross-disciplinary collaboration. Design problems are known to be ill-defined, ill-structured, or “wicked” (Conklin, 2006). Architectural design is a particularly good example of a “wicked” problem, which is of its nature complex and multi-faceted, and to which there is no single answer.

Nigel Cross, in “*Designerly Ways of Knowing*”, describes design variously as “rhetorical”, “exploratory”, “emergent”, and also as “risky”. It is rhetorical in the sense that it is persuasive, creating things that we do not know we need until they are brought into existence, but “also in the sense that the designer, in constructing a design proposal, constructs a particular kind of argument, in which a final conclusion is developed and evaluated as it develops against known goals and previously unsuspected implications”. The research “problem” in this thesis- i.e. “what shall/should we do with wireless sensor networks in buildings for elderly people” continues to evolve during the course of the thesis along with the solution, as the design process advances. The process of iteration generates other problems and solutions not originally envisaged, but which were nonetheless embedded in the original design concept. This is absolutely characteristic of the design process. In the words of Richard MacCormac “what you need to know about the problem only becomes apparent as you’re trying to solve it” (McCormac, 1976). From probing

and refining of the original concept, which takes the form of the development of a proposed solution to a specific design problem, a more generalised concept of an *affective responsive architecture* emerges. This in its turn generates further questioning, producing general conclusions in relation to responsive architecture, in addition to specific context-based proposals.

The methodology is essentially synergistic, and syncretic, drawing together threads from a number of ostensibly disparate disciplines, namely architecture, ICT, and environmental and behavioural psychology - into a coherent proposal as to how wireless sensor networks might be deployed in the future creation of responsive architectural environments that maximise human functioning and wellbeing. From a creative synthesis of information drawn from the review, the thesis explores a theoretical framework and description of a design template for a specific case of responsive architecture, located in the personal life-space of an elderly person with dementia, most likely in a residential care setting.

Thesis Summary

The first chapter reviews research on the effects of specific environmental attributes on the wellbeing of human users, surveying literature on colour, light and biophilia, with commentary on the relevance and usefulness of the available research in the field of architectural design, and on the relative paucity of credible relevant design research. It also introduces the key concepts of “salutogenesis” and “congruence”, from environmental psychology. What emerges is the necessity for a two-pronged approach to the design of environments which maximise person/environment fit, so that issues of both functional and psychosocial congruence are adequately addressed.

Chapter 2 explores the ongoing and symbiotic relationship between architecture and technology, and considers the place and potential of ICT, and in particular, sensor networks, in this context, referring to available contemporary practice and research. Common theoretical ground between architecture and ICT is established, in particular notions of minimalism, elegance in design, and “Machine Beauty” (Gelertner, 1998). Reference is made to the shared critical significance of context both in architecture, and in designing for interaction, which should aspire always to be appropriate to user, context and activity. The chapter concludes with a proposal for a new paradigm for responsive architecture: that of an affective responsive environment.

Chapter 3 begins with a brief summary of the demographic context of the research, which in itself bespeaks an urgent need for provision of suitable housing and care for a burgeoning population of older people in the developed world. Typologies of care architecture, both historical and contemporary, are examined, in order to contextualise the thesis proposal architecturally. This survey also identifies models of best current practice in which the MyRoom proposal is assumed to be set. The notion of the indivisibility of the culture of care from the architecture of care introduced is discussed, raising questions as to how each in turn may affect the other, and thus impact on aspirations towards person-centred design. While much is spoken currently of the need for “person-centred design”, in particular in relation to healthcare design, the critical question for the designer, in order to effectively design for such a paradigm, is to firstly identify the characteristics and needs of the person who stands at the centre of the design model, the real client.

Chapter 4 continues by examining in some detail the user at the centre of the proposed model: that is, an elderly person with dementia. Effects of normal ageing on function and health are described, as are the symptoms of the progressive cognitive and functional decline characteristic of Alzheimer’s disease, as the most common, and increasingly prevalent form of dementia. The intention is to provide the researcher, as a designer, with a practical understanding of the person, with the

aspiration of creating an open design brief, which aspires to creatively address the needs of the individual user in an appropriate architectural setting. The issue of pathologising of behaviours and its effect on built outcomes is also discussed in this context. This section of the review aligns with the idea of designers working “from first principles”, identified by Nigel Cross as characteristic.

From the iterations resulting from the cross-disciplinary literature review, the system characteristics of an adaptive salutogenic room environment are identified, and are consolidated and examined in detail in Chapters 5 and 6.

Chapter 5 introduces the MyRoom proposal, as a localised model for a responsive affective environment. The user interface is envisaged as the built environment as a whole, and more specifically, an imagined personal living-space of an elderly person with dementia. This model is constructed around the trinity of Who? What? Where?, essential in the conception and realisation of contextualised intelligent embedded systems, guided also by the maxim of enhancing environmental “fit” for an individual user, thus promoting wellbeing.

Chapter 6 describes in more detail two linked design proposals which form part of the MyRoom model, and describes the making and testing of a rudimentary prototype for affective interaction. It addresses some of the challenges in terms of skills and education faced by architects who aspire to involve themselves in the area of adaptive/responsive design.

Responsive architecture is implicitly sensor-enabled. In this thesis, affective computing, which incorporates considerations of human emotion, becomes a critical component in a model of user-centred responsive architecture for an elderly user in a residential setting, the inclusion of affective sensing and response being

seen as essential in addressing both psychosocial and functional concerns in order to maximise congruence and usability. Via the process of exploring specific design proposals, conclusions emerge not only in relation to the MyRoom model, as a template for a specific type of responsive architecture, but also with regard to the essential nature of affective responsive architecture. The concluding section discusses the implications of the thesis, including the potential for future collaborative and interdisciplinary research based on the MyRoom model, and its place in responsive architecture enabled by embedded sensor networks.

The concluding section of “Designerly Ways of Knowing” speaks of the need for a broad approach to design research, in order “to construct a way of conversing among disciplines about creativity, in a way that is both interdisciplinary and disciplined”. It is hoped that this thesis, as a piece of design research, contributes to such a conversation between the disciplines of architecture, ICT and environmental psychology, and identifies more of the road-map towards the realisation of genuinely user-centred responsive architecture.

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Chapter 1

The built environment and well-being

- The concept of salutogenesis
- The significance of congruence; models of person-environment fit
- The evidence-base for therapeutic design intervention: factors in the built environment affecting well-being

Introduction

Human behaviour takes place in physical settings, which influence behaviour and functioning in complex and sometimes unexpected ways. The relationship between person and environment is an ongoing process, operating in both directions.

Humans constantly interact with their environments, of which the built environment and architecture form a subset. All environments, buildings included, in turn affect their users, whether those interactions and effects are consciously designed for or not. Neither is it possible for an architect or designer to anticipate all possible user interactions over time, or their consequences to the user. Part of the joy of the experience of architecture is the manner in which such relationships, individual and collective, unfold over time, both in the course of a single experience, and over long and familiar use. As such there is a temporal aspect to architecture not always considered at the design stage, though concerns of seasonality may well be consciously addressed. The extended and intimate nature of user experience differentiates architecture from other art forms, and implies the significance of the profound and long-term effects that the built environment may exert on users. Notwithstanding the subjectivity of the observer, the architect often intentionally designs in such a manner as to manage or direct available possibilities, so as to predetermine user experience to some extent. This may be achieved by directing a route through a building; by setting up “viewpoints” within and from a building; by physically fixing locations for specific activities through detailed design. After a fashion “the possibilities which the work's openness makes available always

work within a given field of relations”, but architecture is still not entirely what Eco defines as an “open work” (Eco, 1989), though remodelled continuously by user experience and perception. However, user experience of architecture is not solely restricted to that of the uninvolved observer; there is also potential interaction through an ongoing process of physical adaptation and modification, both that which is managed through design provision, and ad hoc physical adaptation by a user, or succession of users, over time. Here architecture moves closer to being a truly open work, where the user becomes involved in the final outcome. In attempting to direct user experience, the architect must needs be acutely conscious of the effects of any given design decision, or equally, by an absence of design intention. Whether or not the architect consciously addresses a design issue makes no difference to whether or not the built outcome affects the user, but rather on *how* the user is affected by the experience of the architecture. Architecture is often unavoidable. As the “mother art” (Wright), architecture provides the stage, the vessel, the theatre for human action and interaction, in which it inevitably becomes an active protagonist.

The following section reviews research evidence which investigates how the physical environment, and in particular, the built environment acts on humans. It includes reference to relevant theories from environmental and behavioural psychology, which may be applied to design of the built environment. The review concerns itself primarily with impact of environmental promotion of well-being, in the context of the design of architecture and environments for healthcare.

THE CONCEPT OF SALUTOGENESIS

The salutogenic model of health was first proposed by Aaron Antonovsky in *Health Stress and Coping* (Antonovsky, 1979), arising from his observations of persons who had experienced extreme psychological trauma, but nonetheless remained emotionally healthy, and generally positive in their outlook. This concept was expanded in later papers (Antonovsky, 1987), including in terms of considering individual health outcomes from a salutogenic, rather than pathogenic perspective; in other words, by seeking to identify factors that keep us well, rather than those that make us ill. Prior to Antonovsky's theory, the medical model of health and disease was largely a pathogenic model, which focused on illness and its treatment, rather than on cultivating and maintaining wellness. The general belief was that a person was "well" until they encountered some pathogen which made them "ill", and therefore in need of medical treatment. Not much thought was given to the idea that there might be balancing factors involved in maintaining wellness; preventing disease by promoting wellbeing was largely not considered.

Antonovsky's model, which is now widely-accepted, suggests that an individual's health is a matter of balance between *salutogenic* (i.e. health-promoting) factors and *pathogenic* factors. It is now widely accepted that many factors, such as diet, lifestyle, exercise, etc. can positively influence an individual's health. This notion has been the subject of extensive research into the effects of many such factors, both those which influence health positively, and others which influence it negatively. The World Health Organisation defines health as "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*". (World Health Organisation, 1946)

Antonovsky's salutogenic model of health model postulates that "wellness", specifically in relation to how an individual deals with stress, is strongly influenced by how an individual perceives him or herself in relation to the totality of his/her environment, and how they see themselves as relating to that environment. Stress is known to influence both physical and mental health, and has particular significance in relation to environment and dementia, as we shall explore later.

Antonovsky describes the individual's perception of the relationship with environment as the individual's "*sense of coherence*" (Antonovsky, 1987). This is defined as "*a global orientation that expresses the extent to which one has a pervasive, enduring though dynamic, feeling that one's internal and external environments are predictable and that there is a high probability that things will work out as expected*". Environment in this sense encompasses the social and physical environment; however, the nature of the architectural environment can in itself impact on the social environment. This thesis concerns itself naturally with architecture and the built environment, as a subset of the physical environment.

Coherence, as defined by Antonovsky, is governed by three factors: *comprehensibility, manageability, and meaningfulness*, all three of which can also be readily considered in terms of how the physical and built environment is interpreted by an individual, on an ongoing basis.

Comprehensibility refers to the belief on the part of the person that events occur in an orderly and predictable manner. This enables that individual to have some understanding of those events, and also a reasonable expectation of what future events might be. This factor might translate in architectural terms to clear way-finding, and the appropriateness of a design to function and expected usage.

Manageability implies that the person feels that (s)he possesses the skills, ability, and resources necessary to manage a given situation, or can otherwise draw on supports to do so. It implies that events are perceived of as, or remain manageable/within that individual's control. This factor readily correlates with the concept of Inclusive Design, or Universal Design, where architecture is consciously designed to as to render an environment manageable for the greatest number of people. Where deficits in environmental manageability exist in the built environment, they tend to impact most severely on people who are furthest from the apocryphal "average" user, e.g. on people with disabilities, older people, people with either acute or chronic illness, the very young. At any given time, this

comprises a substantial proportion of the population, yet the notion of inclusive design is relatively recent.

Meaningfulness relates to the capacity an individual possesses to find some meaning in life, for example, a belief that things in life are interesting and a source of satisfaction; that things are really worth it, and that there is good reason or purpose to care about what happens. Environment can support meaningfulness very directly by making provision for carrying out personally meaningful activities, for example, recreational, social, educational etc., at different scales, from that of the city to that of the personal life-space. The degree to which design can either enable or restrict activity is discussed further in Chapter 4.

Antonovsky, from his observations, postulated that the stronger an individual's sense of coherence, the less likely (s)he is to become ill or otherwise adversely affected by stressful events. As medical and neurophysiological research uncovers further links between stress and various illnesses, and the mechanism by which the psychological stress impacts on both physical and mental wellbeing, in both the short and long term, the greater the need becomes to investigate how to minimise or otherwise deal with unwanted or inappropriate stress, both personally and societally. This concern also touches designers of the built environment, as the creators, in many instances, of the forum for human interaction, and in the reasonable belief that proper design of the built environment can make a difference to individual and collective outcomes. As architecture operates at a variety of scales, from the urban to the intimate, it is positioned to make a particular contribution at both the level of the societal and the personal, and at all levels between, through an informed approach to design. Many architects require little convincing: while "common-sense" or "intuitive" approaches to design have been employed for thousands of years in the making of human habitations, many are proven through recent research to have been completely justified. This architect's argument, similar to that of Nigel Cross in relation to design, is that "intuition" is a misnomer for a particular type of human intelligence, both innate,

and cultivated by architectural training and experience, in a competent designer. The minimal available evidence from research carried out in built settings fascinates: it both bears out theory in other disciplines, including theories of congruence and salutogenesis, (both key concepts underlying the thesis), and is explained by research developments in scientific disciplines regarding the precise mechanisms responsible for human interaction with the environment. New technologies and knowledge continue to contribute to how those changing interactions may be mediated through the medium of architectural design. The complex and evolving relationship between architecture and technology, and how it continues to be harnessed to facilitate and improve human-environment interaction is dealt with in more detail in Chapter 2.

How we feel, and what we are, as human beings, is in many ways the collective outcome of all the factors which influence us not only at any given moment, or on a cumulative basis, but also it appears, in evolutionary terms. But the relationships are complex; any environment consists of multiple factors, which interact with one another, at the same time as the user interacts with the total environment. Therefore we must tread with caution when it comes to how research findings are viewed and applied in real-life architectural settings. Scientific research, by its very nature, singles out, narrows down, and restricts the view, in order to be able to say with some certainty that this is this, and that is that, that X cause produces Y effect. Design, and in particular, architectural design, is in many ways the antithesis of research: it adopts a synergistic and holistic approach to producing complete design outcomes. Neither approach is of more value than the other in the real world: scientific research has already beginning to recognise and adopt iterative design-based approaches, while architecture has begun to learn, or rather, to substantiate, “intuition” from firm research evidence. Where caution must be exercised is in acknowledging that the straight application of research to design is no guarantee that the end result will satisfy any of the requirements of “good design”. While a successful design should comply with the requirements of a checklist for Inclusive Design, merely ticking the boxes in relation to those requirements is no guarantee

of a successful design outcome. This has been well demonstrated in the area of “accessible design”, as a precursor to the concept of inclusive design. This apparent paradox continues to be manifest in contemporary healthcare architecture. Truly inclusive design, in any discipline, must centre itself on the individual user, whosoever (s)he might be. The pleasant surprise for many designers, architects included, is that a successful inclusive design is very often not immediately apparent as such, but only as work of quality, where its inclusivity is manifest through ease-of-use for a majority. Very often, considerations of usability for those who might only lately have been casually assumed to be on the “periphery” of the norm - the elderly being the most obvious and topical example, result in innovative and creative approaches to design of products and environments which offer enhanced functionality, or “user-friendliness” - in short, better design. For at least some designers, the author included, these concepts are an essential prerequisite of any artefact, buildings included, that presumes to describe itself as a piece of “good design”. To repeat an oft-quoted maxim: “good design enables, bad design disables” (EIDD, 2004). People show preferences for using designed objects that they like, and which appeal to them. Don Norman refers to this property of the designed object as “Emotional Design” (Norman, 2004), which goes beyond bare functionality.

Good design also observes more than aesthetic considerations: as architects we would do well never to stray far from the Vitruvian ideals of “commodity, firmness and delight” (Vitruvius). Too many buildings of the 20th century have sacrificed accepted notions of “delight” to what are largely intellectual conceits of rudimentary functionality as the generator of form, and latterly, any notion of commodity, if interpreted as “fitness for purpose”, to the hegemony of a given design aesthetic. Every other street-corner is occupied by an “iconic” building; the very term “designer” has become so devalued and debased, that “design” is largely perceived by the public as a matter of superficiality. It is not so, and in assuming the inherent truth of this statement, this thesis sets out to build on the tenet that design can make a profound difference to how individuals may live their lives, and

that technology has always been an intimate part of that equation, and will continue to be so, in ways that have been only barely considered. It has a particular brief to examine how sensor technologies might contribute to architectural design, and pursues this query through consideration of how they might be used to mediate person-environment interaction in the most intimate fashion.

It is important to realise that stressors are not all inherently pathogenic; rather, the individual's ability/inability to deal with stress is the salient issue. Short-term stress has in general a positive effect, while inappropriate, and in particular chronic stress, which an individual is unable to cope with, is pathogenic, and now recognised as a major causal factor in illness. "Appropriate" stress may be taken in the context of the built environment as adequate levels of environmental or sensory stimulation, balanced with usability.

THE SIGNIFICANCE OF CONGRUENCE; MODELS OF PERSON-ENVIRONMENT FIT

Congruence, or person-environment "fit" (Kaplan, 1983) (Kahana, 1982), is a second key concept underpinning the thesis. An appropriate physical environment, which supports congruence, can contribute to an individual's sense of coherence.

Congruence can be sub-divided into *functional congruence* and *psychosocial congruence*. *Functional congruence* is a measure of how well an environment facilitates instrumental tasks, i.e. does the setting provide sufficient space for the task in question? Is the space suitable? Are there sufficient resources available and to hand to carry out the task? Are the ambient conditions comfortable? Is there sufficient stimulation? Or is there too much stimulation? For example, an overly noisy environment may impact negatively on performance of cognitive tasks.

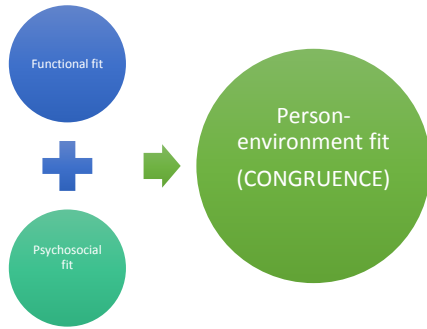


Fig. 1.1 Congruence

A simple example of making provision for functional congruence in the physical environment is to consider the items necessary in order to read a book. It also serves to illustrate how user needs, which must be met in order to provide a congruent functional environment, can vary over time. Most adults would consider a chair necessary to read for any length of time, and also perhaps a table, on which to place the book, or take notes. Lighting levels adequate for reading are also a necessity. As we age, the level of illumination required increases significantly, in terms of both functional and psychosocial need. Good natural light will always need to be supplemented indoors by artificial lighting, both background and task lighting, to cater for daily and seasonal changes in daylight. Most people from their 40s on require reading-glasses, in which case a table may also serve to provide a place to put them when not in use, as it might also provide a place for a drink or snack.



Fig. 1.2 User needs vary over time, and from person to person

Psychosocial congruence, on the other hand, is concerned with how well an environment facilitates psychological and social well-being, by contributing to fulfilment and psychological health. Examples of how built environment may contribute include provision of sufficient space for rest and relaxation, opportunities for personalisation, and allowing for a “personal life space”. We might also consider if there are opportunities to socialise in an appropriate setting, as well as privacy when needed. These aspects will be given more detailed consideration at a later juncture, with specific reference to the residential care setting for an elderly user. In the built environment, the same feature often, and sometimes inevitably, addresses both functional and psychosocial needs. This includes conscious design interventions by the architect. It can also be argued that any decision made in the process of making a building, resulting in any physical intervention, alters the finished design outcome, including by having aesthetic implications. Returning to the example of reading a book: by meeting the functional need by providing an environment conducive to reading, provision is also made for supporting psychosocial congruence. Reading may in itself contribute to self-actualisation and self-esteem through learning, and at the same time to relaxation. The simple provision of a quiet and private place to sit also facilitates certain types of intimate social interaction: a one-to-one conversation, or simply a need to be alone quietly. The manner in which architecture may simultaneously fulfil both functional and psychosocial needs will be explored further in discussion on design of care settings in Chapter 5.

Thus the physical environment itself, by promoting or preventing congruence, and thus reducing or increasing inappropriate stress, can actually contribute positively or negatively to individual and collective well-being. Part of the scope of this thesis is to examine in detail the relationship between person and environment, in order to construct a better design brief for supporting congruence, both functional and psychosocial, in the general sense, and more specifically for the person who is at the centre of this model for person-centred design: the elderly person, especially the person with dementia, living in a supported setting. Stress is of particular

significance in the case of the person with dementia, who has a significantly lowered threshold for environmental stress (Lawton, 1975). This is discussed further in Chapter 3. Stress is also a significant factor both in the onset and prognosis of dementia: midlife stress is a known predictor for dementia in women (Johansson, L., Guo, X. et al, 2010), while an acutely stressful life event, such as the death of a spouse, often presages the onset or diagnosis of dementia in an individual (Charles, E., et al, 2006). In a century where lifestyle stress is so often perceived as the bogeyman, the idea that stress might be so intimately implicated in dementia is of obvious concern.

Eve Kahana's congruence model of person-environment interaction theorises that good "fit" in terms of congruence is seen as a prerequisite for well-being, rather than as being synonymous with it (Kahana, 1982). Reduced to basic principles, either the person can adapt to the environment, in order to achieve congruence, *or* the environment can be adapted or adaptable to the specific needs of that person. While this applies to all users, the ability of the person to adapt varies for certain identifiable user groups, and over time for a given individual. In general, our capacity to adapt to stressors, including environmental stressors, decreases as we age. Kahana also suggests that the needs and preferences of the individual must always be compared with the environmental characteristic, specifically in the context of evaluating residential care settings for elderly people (Kahana, E., Liang, J., Felton, B. J., 1980). Though this is generalizable to any individual and any context, it is obviously of greatest concern in buildings for people with cognitive or physical impairment, where a lack of fit, through inadequate or insufficiently thoughtful design, will result in an exaggerated impact on the user, often arising from sensory and perceptual deficiencies. In any healthcare setting, person-environment fit for the patient/resident will be subject to considerations which will not operate to the same degree in other building types. For example, in an acute hospital setting, a patient may be physically incapacitated, immobilized, in pain, or may require very specific environmental conditions. This user will also be unfamiliar with the environment in which they find themselves, while also in all likelihood

feeling highly stressed by her illness. In mental health settings, the user's psychological condition may affect perception. In long-term settings, which are more specifically the concern of this thesis, the particular characteristics and needs of residents must be carefully considered when making design decisions, based on an identified aspiration to create a total environment which is genuinely "user-centred". Specific issues relating to design for people with dementia, arising from associated cognitive impairment, will be dealt with in detail in Chapter 3.

Person-environment fit can also be viewed in terms of adjustment (French, J. R. P., Rodgers, W., Cobb, S., 1974). If an environment is incapable of being successfully or appropriately adapted to the individual, it will inevitably become a source of stress, and thus negatively affect well-being. It is therefore in precisely the circumstances that pertain where a vulnerable person is generally restricted to a specific environmental setting, such as occurs frequently in residential care, that congruence between the user's needs and the environment take on the greatest significance. Thus, a successful environment will be designed to support not only survival needs and instrumental tasks, but also psychosocial functioning. Kahana stresses the necessity of recognising the impact of the "personal life space" (Kahana, 1982) of the individual, which in the model proposed in this thesis, is assumed to be the resident's/patient's own room. It is of interest with reference to the broader implications of this thesis, and any future research, that Kahana further maintains that the congruence adaptation model can only be tested longitudinally, i.e. over time. Her view resonates with currently proposed approaches to architectural design research.

The idea that design and physical context can measurably affect user well-being has gained credence over the past generation, underpinned both by theory in environmental psychology and other disciplines, and by emerging research, including that intended to support evidence-based design, which may be defined as "a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed

client, about the design of each individual an unique project” (Stichler, J. F., Hamilton, K. D., 2008). It is by now well-recognised that stress is the root cause of many illnesses, both psychological and physical, through its effects on the immune system (Khansari, D. et al, 1990) (Kemeny, 2007). In the context of healthcare buildings, the relationship between design and health outcomes continues to be researched. The concept of “salutogenic design” (Dilani, 2009) has been embraced in the area of healthcare design for obvious reasons: for example, certain aspects of design have been demonstrated to reduce length of patient stays and need for analgesia, and are therefore of interest to healthcare-providers (Lawson, B., Phiri, M., 2003). In the case of residential care, including for elderly people, the issue is not one of reducing patient stays, but of facilitating quality of life and optimizing independence, which are less easily measurable.

Models of person-environment fit

Maslow’s “hierarchy of human needs” (Maslow, 1943) is possibly the best-known model of person-environment fit, and though it was developed in relation to the social environment, its principles may also be applied to the built environment. It has been referred at this juncture, after other theories, as it has very often been interpreted in a literal and restrictive fashion, including in relation to design of the built environment.



Fig. 1.3 Maslow's Hierarchy of Human Needs

A serious criticism of the model, in the manner in which it impacts in practice on both the design and management of healthcare settings, is the inevitable tendency to prioritise those needs that Maslow has placed at the base of the pyramid, at the expense of “lesser” needs, whether or not this was his intention. An extreme though unfortunately common example, in care provision, is the physical restriction of elderly patients (through use of straps, restraints etc.) in a literal and simplistic interpretation of the need for safety. These issues do not arise to the same extent in other settings, such as a person’s own home, where individual choice is much more likely to inform any situation. The same viewpoint has negatively informed the architecture of many care settings, though it may be acknowledged that the consensus as to the best model of care changes from generation to generation. In an appropriately-designed setting, with sufficient level of supervision/support, this necessity simply should not arise, but the tendency has been to look on the patient as the problem, rather than the environment to which that person is expected to navigate, often quite unreasonably, given the circumstances and the typical characteristics of the user. There have until lately been few attempts to provide adaptation or flexibility which is cognisant of actual user needs. It is to be expected that older existing care settings will fall shorter of actual user needs than new-purpose-built environments, but even in the latter, there is frequently a chasm between what a user might reasonably expect of a residential setting, and what is considered appropriate, or rather sufficient, by the care-provider. The humanity and individuality of the individual is too often overlooked, and conveniently excluded from any real consideration in design briefs.

Survival needs vs. well-being needs

Biologist Stephen Boyden, viewing human needs from an evolutionary perspective, distinguishes between “survival” and “well-being” needs” (Boyden, 1971), which align well with the concepts of functional and psychological congruence respectively. He defines the “biological determinants of optimum health” as “the conditions which tend to promote or permit an animal optimal physiological, mental and social performance in its natural evolutionary environment”. Survival

and well-being needs are not mutually exclusive. Boyden also refers to a need for meaningful change and sensory variability, and for an interesting visual environment that includes aesthetic integrity, maintaining that such environments can support the need for knowledge and understanding. It can readily be observed that in the design of many contemporary care environments, concerns regarding safety still take precedence, with the hierarchical Maslow model being used as justification. Safety regulation may be subjected to such a narrow interpretation that it presents barriers to the provision of an environment that is psychosocially supportive, by restricting the options available to the designer. Aesthetic and design options become artificially narrowed by restrictions on use of materials, details, design features. Safety concerns may be prioritised to the extent that they actually *damage* the capacity of a care environment to adequately address psychological and other higher needs. Nowhere is this more apparent than in the realisation of care environments for the elderly. Curiously, the recent concerns manifest in design of appropriate, human and stimulating environments for people with intellectual disability has yet to be taken on board, in this country at least, in the provision of environments for the elderly. Appropriateness in this context implies considerably more than mere physical accessibility. Organisational culture can therefore not only influence the level and form of care provided, but also the physical context of the care setting. The needs identified by Boyden also correspond with those categorised by Maslow's hierarchy. To provide (or design) health-promoting environments for human beings, Boyden maintains that one must understand the complex set of relationships which have evolved over time between human beings and the settings in which they live. He perceives a frequent mismatch between our evolutionary environment and modern, industrialized environments. The same comment might be applied to a majority of healthcare environments, in which the user is treated in an institutional fashion, that is, in a different manner from a "normal" "well" person, and where even common-sense considerations often appear not to apply. The oft-repeated joke about patient being woken up to take their sleeping pills springs to mind: a similar lack of correspondence between needs and affordances in the built healthcare environment is also often present. Similarly, Spivack, in his theory of archetypal space (Spivack, 1973) proposes that

people function best when their environments afford places consistent with basic behavioural and emotional needs. Whether or not contemporary care settings actively support optimal functioning of residents is questionable.

Kaplan emphasises the “cognitive compatibility” of the environment as a fundamental need (Kaplan, 1983), compatible environments being characterized by the presence of important resources, such as controllability and information, and the absence of attributes that are inconsistent with optimal perception and cognitive functioning, for example, distractions, excessive stimulation, confusion. He also addresses a significant concern which had not been adequately addressed in person-environment congruence theory: is the absence of stressors alone enough to produce a sense of well-being, or does well-being depend on the presence of different types of environmental stimuli and attributes? Referring to Antonovsky and Boyden, the answer to this question would appear to be in the affirmative. However, while architects may strive through their designs to provide not only firmness and commodity, but also delight, in keeping with Vitruvian principles, the latter has too often been overlooked when faced with the sometimes overwhelming functional requirements of the modern care setting. Not infrequently, even where aesthetic considerations have been made paramount in public or shared spaces, the patient’s room is still, more often than not, a neglected thing, all the more ironic given that the user may, or in certain circumstances, is obliged to spend the greater part of their day in what is their “personal life-space”. It is of critical significance in long-term settings, though this has been barely recognised to be the case in the manner in which design briefs are formulated in many countries. It is important to remember that while it is vital that basic needs, such as survival and comfort, are provided for, there are other needs, which Maslow considers to be of lesser importance, but which must also be catered for in any healthcare setting that purports to be patient-centred. In the hands of a good designer, it is possible to create an environment which is successful in terms of creating a home-like residential environment appropriate to the needs of a resident with specific needs, including dementia. Where an environment fails to provide for basic survival needs, such as food or shelter, serious illness or death will result; this is fundamental. However, Boyden further theorises that lack of psychosocial

congruence can lead to what he terms "*The Gray Life*" (Boyden, 1971) of psychosocial maladjustment; of depression, aggression, and furthermore of stress-related physical illness. The term is singularly and unfortunately apposite in describing the likely outcome of placing any humans, let alone vulnerable elderly people, in the types of environments which have come, until very recently, to typify the residential care setting for the elderly. Over-zealous implementation of regulation can operate so as to restrict choice to the degree that it may contribute to physical stress, inappropriate cognitive load, and lack of stimulation, through a combination of unsuitable environmental conditions and insensitive and regimented management systems, which often seem to go hand-in-hand. Considering that dementia is the single greatest factor likely to lead an elderly person moving into residential care, the possibility that existing care environments might actually worsen dementia-related behaviours constitutes an appalling vista.

General needs vs. needs of specific user-groups

In short, humans possess general characteristics which can be used to formulate guidelines for the design of psychosocially supportive environments, though some adjustment may be needed with respect to the differences and needs of each individual, particular within an elderly or ill population, and necessarily more so in the case of users with severe cognitive or physical impairment. However, it should not be forgotten that these differences are variables in the context of a set of basic common human needs. It has been used as a convenience, and still is, to assume that older people, for example, are somehow significantly "different" to the rest of us, enabling us as a society to consign them to care settings with which a healthy individual would be likely to express extreme dissatisfaction. Buildings which are well-designed can be considered an appropriate architectural response to basic shared human needs. Many of the design issues addressed in exemplars of good healthcare design also have application right across the architectural spectrum. The thesis therefore never proposes that use of technologies should replace good design, but rather that use of novel technologies should not be confined to addressing purely functional concerns, but treated holistically as an architectural

design intervention, and dealt with in a coherent and integrated fashion. The possibilities afforded through use of ambient technologies can enable adaptivity and responsiveness, rendering care settings more appropriate to the needs of specific user-groups. Such interventions have greatest potential in the case of acute care environments with critically ill patients, or as an ongoing and adaptable support system for long-stay residents of care facilities who have restricted mobility and/or cognitive impairment. It must always be borne in mind that enhanced vulnerability arising from illness or other impairment will impact negatively on a user's interaction with an environment, in particular where sensory and/or perceptual deficits exist. As with physical accessibility, there is a spectrum of ability, rather than firm dividing lines between "normal" and "impaired". It is in this context that the effect of environmental stress, exacerbated either by illness or incapacity, must be taken into careful consideration.

Good design is conscious of its power to influence the user, and therefore uses it carefully. It is at the behest of the architect to use design to promote the process of salutogenesis in the built environment, by designing environments, which are "psychosocially supportive". Alan Dilani describes this as design which "stimulates and engages people, both mentally and socially, and supports an individual's sense of coherence" (Dilani, 2001). The potential for beneficial impact is most obvious in healthcare architecture. The immediate physical environment of the patient's own room must be given special priority, so that aspects of the physical environment are treated individually and collectively through the process of design in such a fashion as to optimise patient/ environment fit, or congruence.

THE EVIDENCE BASE FOR THERAPEUTIC DESIGN INTERVENTION: FACTORS IN THE BUILT ENVIRONMENT AFFECTING WELL-BEING

Evidence-based design (EBD)

The field of evidence-based design came into being roughly thirty years ago, derived from the idea of evidence-based medicine, and is most often referenced in the design of hospital and other healthcare architecture. The effect of considered design interventions in healthcare environments is, unsurprisingly, a major area of research, both in the light of evidence of the salutogenic effects of design, coupled with a growing realisation that traditional hospital models may not be making any positive contribution to patient and staff well-being. Research carried out in Japan has demonstrated the negative effects on patients of a traditional acute hospital environment, even in the very short term. (Cooper, 2006) The following section examines the literature, both theoretical, and empirical, on how various distinct aspects of the physical environment affect human functioning, specifically in terms of how they affect well-being. Some of the theory is borne out by research in Evidence-Based Design. The intention is to develop as comprehensive as possible a “tool-kit” of factors that might be consciously manipulated by the designer, most particularly in settings where the wellbeing of the individual user becomes a paramount concern. This includes architecture for healthcare, and for residential settings, domestic or otherwise, for particularly vulnerable groups of individuals. The same concerns should, of course, extend to all environments in which humans work and live, in order to maximise not only well-being, but also thus productivity and other outcomes viewed as positive. However, care settings are a good place to start, given that environment has a greater more immediate and more immediate impact on these users, either in positive terms, or where there are environmental deficits which impact negatively on human function and well-being.

Relatively recent research has begun to consider the precise nature of the interaction between person and environment, investigating the implications of specific design interventions and aspects of built environment on user experience and outcomes. This is seen to be of greatest concern where users are perceived of

as particularly vulnerable, namely, in healthcare settings, whether they be in acute hospitals, in architecture for clients with special needs, and especially in residential care, where any impacts, positive or negative, are played out over time, with the greatest potential for harm or good. While intentions are positive, a note of caution must be sounded: credible research into the effects of built environment must be carried out insofar as possible in the built environment, in order for research outcomes to carry any weight with practitioners. While this has begun to happen, the pool of available research is still very small. At the same time, scientific research almost always tends to a reductionist approach: that is, the consideration of one single factor, with the exclusion of as many variables as possible. This runs directly contrary to design thinking, which is synergistic and iterative in nature. A real-world design solution aims at the “best possible”, given the constraints of brief, time and financial resources. There are no absolutes in design, no single perfect answer. Successful design solutions synergise many aspects for the physical environment, by manipulation of space, light, materials, detail, colour and so on. No successful architectural solution rests solely on a single aspect, though research has very convincingly demonstrated the profound impact of certain factors, most notably availability of natural light on building users (Hobday, 2006). In the built environment, the effects of any single design intervention often become inextricably intermingled with the effect of other factors which may not necessarily be considered. A single intervention may have multiple outcomes. The way forward, where possible, is research in completed buildings, where the possibilities offered by sensors and sensing offer intriguing possibilities. Experienced researchers reviewing available design research for built environment sometimes find it to be hopelessly naïve in terms of incautious conclusions drawn, and therefore also any aspiration to real usefulness in practice. At the same time, while much architecture is recognised as innovative and exploratory, the results of design exploration are rarely categorised and formalised as academic research. While design is not research, it can be used as vehicle for research, and research in other disciplines has been shown to benefit from an iterative approach, such as is at the core of the design process. Design-based approaches include a tolerance for calculated risk-taking, and acceptance of possible failure. It might seem like a

statement of the obvious, but until such time as architecture and the design professions become more actively involved in design research relevant to their own disciplines, useful real-world impacts to research are likely to be self-limiting. Evidence-Based Design can be extremely useful to the designer in justifying decisions to a sceptical client, especially when it comes to the need for additional cost, where benefit can be demonstrated in for example, reduced patient stays, reduced need for medication, or other evidence of enhanced user well-being, which of course, is a critical issue in healthcare. At its worst, compliance with evidence from research can be used to defend poor design, in the same manner in which accessible or universal design has been reduced in some cases to a mere ergonomic box-ticking exercise. Good design is far more than the sum of its parts. Out of this truism arises what may well be a perennial, as well as contemporary dilemma for design research: a need to develop methodologies more appropriate to the subject-matter, but whose outcomes are accepted as credible within the academic community as a whole.

Colour and Light in the Built Environment

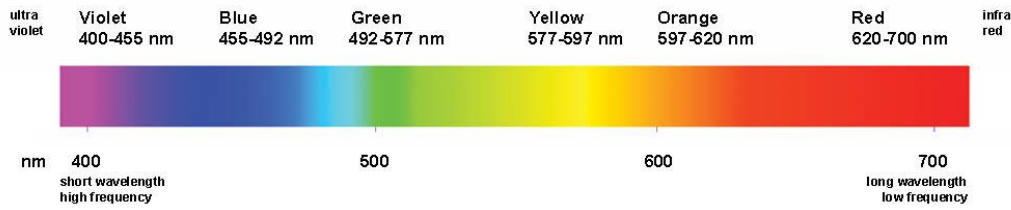


Fig. 1.4 *The visible electromagnetic spectrum*

The belief that colour, or individual colours, have specific properties, including the ability to alter or produce particular moods, is popularly held. Such beliefs have existed since ancient times in many cultures. Colour, both applied, and intrinsic to materials, has been employed in by humans since the earliest habitations, and continues to be used in an often intricate and considered manner, especially in designed environments. Both designers and lay-people need little by way of convincing of the importance of colour, not only in creating spaces that are aesthetically pleasing, but beyond that, that colour can influence ambience and mood. Despite the persistence and popularity of such beliefs, research and concrete evidence demonstrating psychological effects is fragmented, and for the researcher of the built environment, in many ways inconclusive or unconvincing. Many researchers have sought to demonstrate that exposure to specific colours causes specific psycho-physiological effects, but a survey shows that research findings are often contradictory and on the whole unconvincing (Brent Tofle, R. et al, 2004). Some of the methods used might be viewed as unscientific, or if scientific, as taking place in such a limited context as to have no meaning or application in the real world, and specifically, in the built environment. A common enough example is the use, in colour research, of colour cards or small paper samples, and exposure to colour for very short periods of time. This is not to say that colours do not affect us, but that the manner in which this happens is complex, may involve exposure over time, and is therefore far from simple to research. It would also seem counter-intuitive to state that colour in the built environment does *not* affect us. However,

there is still no convincing evidence for “one-to-one mapping between colour states and emotional states” (Wise, B. K., Wise, J. A., 1988).

What we describe as “colour” is human perception of certain wavelengths of light, which we describe as being in the “visible” portion of the electromagnetic spectrum. All this implies is that human beings are equipped with the necessary receptors and neural capacity to receive and process specific wavelengths, which we then perceive as a visual phenomenon. Other species “see” colour differently, and wavelengths which we do not process visually appear as visible to them. It should always be remembered that colour is a function of light, and that some of its apparent effects are bound up in what are described more generally as the effects of light. Plato maintained, quite correctly, and presciently, that *“nothing is self-existent....what we term the substance of each colour is neither the active nor passive element, but something which passes between them, as is peculiar to each percipient”*. (Plato) It can be argued that each individual sees colour differently; however, the degree to which perception varies between individuals of a species is debatable: if recent theory to the effect that colour vision evolved largely in order to identify emotion in other humans is correct, (Changizi, 2009) this requires a degree of consistency in perception across the human species, and conversely, the possibility of some general consistency in emotional response to colour. It might therefore be reasonably be assumed that there is consistency in how a majority of humans perceive or experience certain colours; without this, it would be difficult for much visual art to be possessed of any shared value or meaning. While certain colours have different symbolic meanings in different cultures, for example, colours used as an expression of mourning, there are nonetheless broad similarities in colour preferences across different cultures (Rosotti, 1995). Such research still has little to tell the architect about use of colour in buildings, as it commonly refers to six or seven basic colours, whereas a myriad of hues and shades is available for use as applied or intrinsic colour. Some research on colour preferences in different groups, e.g. older people, has little to offer by way of application to the built environment when the methodology consists of subjects looking rapidly through a large number of colour-cards. (Wijk, H., Berg, S., Sivik, L., Steen, B., 1999)

The experience of colour of the built environment tends towards the immersive, because it is used and experienced in three dimensions, at room scale. There is useful research which identifies a preference for a paler colours in long-term care environments, on the part of older people (Dalke, H., Matheson M., 2007), and also recommendations for use of lighting which provides accurate colour-rendering, to compensate for changes in perception of brightness and contrast as we age, but it is perhaps the information which deals with changes in sensory perception as we age that is of most practical use to the designer, as it is not overly-prescriptive, and leaves the designer to draw her own final conclusion in the realisation of a complete design. In the built environment, we also experience colour over time, including over longer periods of time, if one acknowledges the likelihood that many of us will spend much of our time in a limited number of places, namely, where we live and work. In normal experience of buildings, we are usually not exposed to coloured light, but rather, applied pigment in daylight, or a facsimile of daylight. While different light sources change our perception of certain applied colours, generally pigments do not appear to change, while dyes do. The spectral composition of sunlight varies over the course of the day, and seasonally; daylight therefore changes in both colour and intensity. At low levels of illumination, “warm” artificial light makes our surroundings appear “natural”. Conversely, as illumination increases, a natural appearance is achieved by using cooler light sources (Kruithof, 1941). Our visual processing appears to adjust to the changes in natural light over the course of day to the effect that colours viewed appear to remain the same under what are quite different lighting conditions, a phenomenon known as “colour constancy”. The perception of colour in internal environments is in part determined by the reflective and absorptive qualities of the surrounding environment, and the length of time observing the colour. Colour temperature of light sources is known to influence both mental activity level and autonomic nervous function. Higher colour temperature lighting was found to increase mental activity. (Deguchi T., Sato, M., 1992), while similarly having a more activating effect on autonomic nervous function (Mukae, H., Sato, M., 1992).

Faber Birren, a noted 20th century authority on colour in the built environment, distinguished between the psychological and physiological effects of colour (Birren, 1983). Arguably, as means of detecting the effects of colour become more sophisticated, and more is discovered about how the body's systems, for example the nervous and endocrine systems, are interdependent, those effects may come to be seen to be one and the same. Bio-sensing might thus be used to measure physiological signals which are expressions of a change in emotional or psychological state. Birren's research, some of which uses a polygraph to measure respiration, pulse and skin conductance, tended to focus on the psychological and emotional effects. Results stress that the effects of colour are always temporary. Humans do display physiological response to colour (Kaiser, 1984), but those responses may be influenced by association and personal preference. Birren comments that the "functional" use of colour, that is, its practical application in the built environment, should ideally be "designed around the use of a variety of colours in order to keep human responses continually active and to avoid visual adaptation or emotional monotony." Colour research has sometimes, for example, sought to compare the effects of two discrete colours to one another: the result of such research may have little practical relevance in the scenario described by Birren, which is also the domain of the architect. Development of methodologies which facilitate research of the effects of colour at the scale of the built environment, and in live settings, is desirable. It might serve to broaden the understanding by designers to the role of colour in the built environment.

While many of the perceived effects of specific colours may arise from either cultural or personal associations, there also exists the possibility that some of those associations are not merely conditioned, but that we may, as a species, have developed evolved preferences. It might therefore be appropriate that while architectural colour in the public forum and in public areas should consciously draw on shared cultural associations, that much more detailed consideration be given to the use of colour in the personal life space, most specifically when that is restricted

for the individual in question. This immediately raises the issue as to whether a single colour can be appropriate for all activities or conditions likely to occur in that space.

The difficulty in establishing therapeutic benefit of colour, as it is popularly imagined to exist, may lie in the very fact that experimentation has sought to attribute specific benefit for single colours. Whilst this seeks to reduce the effect of colour to a measurable quantity, it might arguably be viewed as an overly simplistic model of how colour operates in the physical environment, and particularly, at the scale of the built environment. The expectation of a defined physiological response to a single colour might well be likened to hoping that a single musical tone will produce any sort of psychophysiological effect. Few would assume this to be the case: while listening to a musical *composition* has been demonstrated to be effective in reducing anxiety and pain (Nilsson, 2008), it is stretching credibility to propose that listening to a single tone being sounded would have any useful benefit, though musicians and composers do ascribe particular “moods” and characteristics to each scale of an octave. A musical scale, however, is based on a mathematically-constructed set of relationships based on pitch; the Pythagorean structure of Western music has its roots in ancient Greece. To extend the musical/visual analogy, if a single note is the equivalent of a single colour, then a painting or static image might be the equivalent of a chord, while a video or film with continuously moving images might then be likened to piece of music, as might a three-dimensional environment. Moreover, colour in the architectural environment acts as one element of an aesthetic composition; it does not exist in isolation from other aspects of the built environment, or even from other colours, which simultaneously form part of the user’s experience. In addition, colour in architecture also has a temporal aspect, as the observer’s experience of architecture is also extended over time. To quote Neutra “colour perception, like form perception, takes place in the space-time continuum. To treat it in relation to space alone is a defective concept” (Neutra, 1954). The built environment, however, affords the designer the opportunity to use colour at a scale unachievable

in other contexts, and if there is any benefit to be attributed to single colours, it is in the built environment that this is most likely to have a measurable effect.

Research methods to date have not facilitated testing at the scale of the room or architectural space.

Observed Effects of Colour

Red and blue are at the extremes of the visible spectrum, and incur different biological reactions, exhibited also in plants and in animals other than humans. In humans, exposure to the colour red increases blood pressure. It also increases skin response, indicated by decreased Galvanic Skin Resistance (GSR), excites brainwaves and increases muscle tension. Blue, at the opposite end of the visible spectrum, tends to have the opposite effects, lowering blood pressure and pulse, and increasing GSR (Jacobs F. W., Hustmeyer, F. E., 1974). Reactions to orange and yellow are similar to reactions to red but less pronounced. Similarly, reactions to purple and violet are similar to those to blue, while green is neutral in terms of provoking physiological reactions. Recent research from the University of British Columbia has demonstrated the ability of red versus blue colours to enhance cognitive performance (Mehta, R., Rui, J. Zhu-, 2009), which is of obvious interest in design of spaces for work, and in educational environments, as well as the contexts of advertising and product design. The question for the architect is how to usefully address this knowledge and use it in design, taken against the backdrop of previous research about the effects of red in the built environment. The question of suitability of specific approaches for design at different scales, and in different contexts also arises. The reaction of an individual to a particular colour may, of course, also be influenced by cultural conditioning, as by personal experience.

Visibility and ease of use are affected by what is termed “brightness engineering” which implies control of colour *as it is perceived*. All areas of the field of view being illuminated uniformly is not suited, for example, to cognitive tasks, which are best supported by brighter localised light, with medium tones use in the background. In contrast, where the attention is best directed outward towards the surrounding

environment, brighter colours are more appropriate (Birren, 1983). Brightness and contrast are more strongly related to colour perception than hue itself. Perhaps most interestingly, Birren maintains that “visual and emotional comfort demands constant change and variety”. This might also be interpreted so as to suggest that designed environments should ideally emulate the variety of the natural environments in which we evolved.

A more recent and fairly comprehensive survey on the use of colour in healthcare environments has also commented critically on methodologies used in the research reviewed, e.g. “inconsistent findings in the colour literature reflect the different methods used, poor study design, conditions, sample sizes or test protocols” (Bosch, S. J. et al, 2012). A fairly comprehensive UK study of colour in healthcare environments, while it makes useful recommendations, particularly regarding use of non-saturated colours, and colour cuing (Dalke, H., Matheson M., 2007), relies heavily on a methodology which utilises mock-ups of room colour schemes, which while intended to be immersive, is still at odds with the manner in which a competent designer in practice selects colours: while coloured drawings are used in the early stages of design, in many years of practice, I have once only neglected to use in-situ colour samples prior to colour selection, and regretted it, as the size of the colour sample invariably affects the perception of colour intensity, as does orientation and ambient lighting level.

To put it colloquially, “the jury is out” regarding definitive effects of colour in built environment, despite initial high expectations when embarking on a review of the literature. This is stated with the caveat that the designer must be mindful, based on recent research, of accommodating changes, and more critically, deficiencies in perception, in certain designed environments. Other than that, the realisation of an environment that is deemed aesthetically pleasing still has greatest currency, while the complex and interacting factors that govern what is perceived as “pleasing” remain largely to be determined. If we wish to elicit a beneficial (that is, stress-

reducing) response to colour in the built environment, it is therefore reasonable to suggest that what must be tested is a composition of colours, be it abstract, figurative, or naturally occurring. This will be discussed further in Chapter 6.

Light

“Where the sun does not go the doctor does”

-old Italian proverb (Hobday, 2006)

Colour in architecture must not be only considered in terms of applied, or subtractive colour, but also in terms of lighting, and use of light in general, both daylighting and artificial. New technologies and materials also suggest design possibilities for use of transmitted/additive colour in internal environments. In contrast to the paucity of credible evidence in relation to colour, there is a significant amount of convincing empirical research, in the field of chronobiology. We are creatures of the light, dependent for our very existence on the sun. Ongoing research demonstrates again and again the effects of sunlight on human biochemistry and metabolism and the many and significant effects of lack of exposure to sunlight; thus, light does not merely affect us visually, but systemically. Light, or its absence, can profoundly affect our well-being, both in terms of its effects on our immune systems, and our psychological state (Hobday, 2006). Through research, our understanding of the biochemical mechanisms by which these effects are moderated has increased hugely in recent years, giving growing insight into how the built environment, and those who design it, have a role to play in promotion of salutogenesis, with the potential to significantly improve the lives of those who occupy and inhabit use the spaces we design.

Exposure to light effectively resets our body clock on a daily basis. This “master clock” is located in the supra-chiasmatic nuclei of the hypothalamus. The hypothalamus functions as the control centre for many autonomic (unconscious) functions of the peripheral nervous system. It is also as part of the limbic system,

which influences emotional responses, as well as regulating endocrine function. The autonomic nervous system (ANS) functions largely below the level of consciousness, and governs, among other things the body's "fight-or-flight" response to stress.

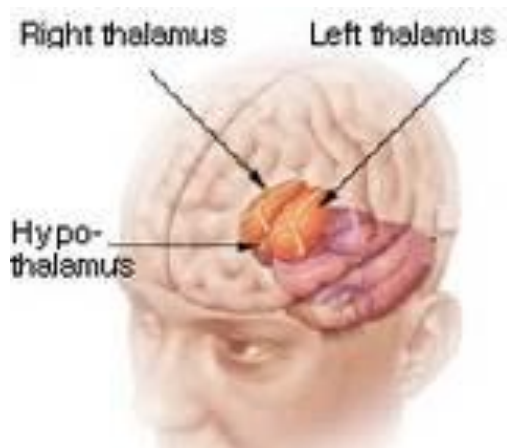


Fig. 1.5 The thalamus and hypothalamus

Credit: SEER Training Modules / U. S. National Institutes of Health, National Cancer Institute

Serotonin and melatonin

During daylight hours, the pineal gland, deep in the brain produces serotonin in response to being stimulated by light; as light decreases in the evening, production tapers off. Production of melatonin, the "hormone of sleep", takes place during the hours of darkness. Rene Descartes, who studied the pineal gland extensively, called it the "principal seat of the soul" (Lokhorst, 2013) and believed it to be the point of connection between the intellect and the body. It is also often referred to as the "third eye". Both serotonin and melatonin have critical roles in human functioning and health. 20-30 minutes of direct sunlight a day is of benefit to elderly people who have difficulty sleeping at night. It is though that the timing of exposure to bright light may be a factor in resetting circadian rhythms, rather than the intensity (Placeholder57). Bright-light therapy, using artificial light, has been successfully used to treat both seasonal and non-seasonal depression by increasing serotonin

production, and demonstrated in a 2005 study to be as effective as medication. Interestingly, individuals with depression, most particularly women, are also at greater risk of heart disease. In addition to association with depression, low serotonin levels are associated with atherosclerosis. Wavelengths in the blue-green area of the spectrum are most effective in prevention and treatment of depression, both seasonal and non-seasonal, and there is evidence to support greater efficacy of early-morning exposure to light (Golden, R. N. et al, 2005). It was only recently discovered that the eyes contain not only the cells known as rods and cones, which are used in vision and most sensitive to yellow-green wavelengths, but a third type of photoreceptor cell, known as ganglion cell photoreceptors, which are most sensitive to blue wavelengths, and appear to be implicated in synchronising the circadian clock, among other functions (Berson, 2003).

Many physical disorders, often seen as “lifestyle” diseases, such as rheumatoid arthritis and heart-disease, are associated with depression (Rugulies, 2002), as is dementia in older people (Muliyala, K. P., Varghese, M., 2010). People with depression have lower bone density, and are more likely to develop heart-disease in later life; prognosis for women with heart-disease is poorer for women than for men as they tend to become depressed after becoming ill (Frasure-Smith, N. et al, 1999). However, female patients in sunny rooms recover more quickly from myocardial infarction (Beauchemin, K. M., Hays, P., 1998). Depression is associated with obesity, both as a cause and effect, and also with endocrine, autonomic and immune dysregulation. The distinction between mind and body, in effect, appears not to exist in relation to health: not only does *mens sana in corpore sano* apply, but the converse appears equally true, that is “*corpus sanus mens sana facit*”. This resonates also with an identified need for psychosocial congruence as a prerequisite for wellbeing, as outlined earlier.

Melatonin not only has a role in learning and memory mechanisms, but also has a specific role in Alzheimer’s disease, inhibiting neuronal death and formation of

neurofibrillary tangles. Neurofibrillary tangles in the hypothalamus of Alzheimer's patients disrupt production of melatonin in the individual, which may be related to sundowning, the term used to describe agitated and restless behaviour in dementia patients, which appears to be temporally associated. Sundowning may be treated with phototherapy (Haffmans, P. M. J. et al, 2001). Melatonin is also anti-carcinogenic, having a role in the immune system.

Artificial lighting has been used for dawn simulation, in order to reinforce circadian rhythms. In a residential care setting where residents, due to a combination of factors, may not spend adequate time outdoors, this possibility should also be considered. Inappropriate artificial lighting can disrupt or enhance these natural patterns: while bright light in daytime boosts serotonin production, exposure to white light during the hours of darkness can disrupt melatonin production. The blue component of white light is the most disruptive of melatonin production, which would suggest that less disruptive red/orange/amber light is a better choice for night-lighting. While variable lighting systems are already commercially available, they are primitive in that the variation possible is not reflective of daily and seasonal variation in natural lighting.

Vitamin D

Sunlight is essential for the synthesis of the pro-hormone Vitamin D in the human body, not only in the skin but also in internal organs. Vitamin D appears to have a fundamental role in regulating body processes, acting as a seasonal regulator of biological activities and photoperiodic rhythms. Deficiency is a significant factor in immune-related disorders, including multiple sclerosis, diabetes, rheumatoid arthritis, and cancers (Ponsonby, A. L., Lucas, R. M., van der Mei, I. A., 2007). Most of these diseases have an increased incidence with age, and it is now well recognised that lifestyle is a contributing factor in some of them. Older people are at greater risk of Vitamin D deficiency, both as they tend to be housebound, and because they are less efficient at synthesising it than younger people. There is a

suggestion that low levels of Vitamin D are associated with dementia. Lower Vitamin D levels are also associated with poor cognitive performance in non-Alzheimer's subjects (Llewellyn, D. J. et al, 2010).

Other hormones

Sunlight stimulates production of dopamines and endorphins, both described as “feel-good” hormones, in addition to cortisone, which controls the anti-inflammatory immune system. Exposure to UV in sunlight lowers blood pressure, cholesterol levels, and blood sugar levels (Hobday, 2006). It should not be a matter of great surprise therefore, that in an increasingly urbanised society where people spend more and more time indoors, diseases such as hypertension, cardiovascular disease and diabetes are on the rise, and are prevalent particularly among older people. At the same time, it must be acknowledged that as little as a couple of generations ago, far fewer people would have survived into old age, and also that is to some degree inevitable that, depending on circumstances, an elderly person, particularly at the point where a move to residential care is necessitated, may not be in a position to spend significant amounts of time outdoors. The question then arises: should internal environments be designed so as to compensate artificially for lack of exposure to natural light? The invention of the light-bulb effectively might well have ushered in the possibility of a 24-hour society, but the huge increases in productivity and comfort enabled by artificial lighting are counterbalanced, or even outweighed by our becoming distanced as a species from an awareness of our natural rhythms, diurnal and seasonal, and largely unaware until recently of the scale of the damage incurred by this separation.

Biophilia, Nature Views and the Aesthetics of Fractals

Humans consistently express a preference for natural landscapes over manmade (Ulrich, 1993); this furthermore manifests itself in positive emotional affect and a decrease in stress when they experience natural landscapes, or even images of

them (Ulrich, 1986). This assertion is based on an expanding body of research on aesthetic preferences, together with a number of theories as to why human beings should exhibit such “*biophilia*”, in aesthetics as in other aspects of the human experience. Views or images of nature, in particular those including views of water, consistently influence psychophysiological states more positively than those of urban scenes, to the extent that they may influence patient recovery (Ulrich, 1984). The term “*biophilia*” was coined by Edward Wilson (Wilson, 1984), to describe the relationship which has evolved between human beings and the natural world, where humans have evolved in such a fashion as to predispose them, through “*biologically prepared learning*”, towards specific types of relationships with natural phenomena which result in advantages in terms of survival. This includes the favouring of certain types of landscapes, theoretically savannah-type, over others. It is theorised that humans favour such landscapes on the basis that they were indicative to primitive man of plentiful supplies of food, as well as the security of an open vista, with cover when required. Research by Roger Ulrich, among others, supports the “biophilia hypothesis” (Kellert, S., Wilson, E. O. Eds., 1993) in a number of areas. Ulrich’s research in particular suggests that natural images and nature views in a healthcare setting have measurable therapeutic effect. Simulated natural views, in the form of slides and photographs, have also been shown to be effective in reducing stress and inducing relaxation in numerous studies (Ulrich, 1986) (Saito Y., Tada, H., 2007). This may be related to the fact that natural images contain fractal patterns, which produce de-stressing effects (Taylor, 2006) (Joye, 2006). It is further accepted that other visual properties such as stimulus complexity, and colour, affect a person’s level of activation or arousal. Research also suggests that images accompanied by sound are more effective than natural images alone (Diette, G. B. et al, 2003). Commercially supplied backlit images of natural scenes have been in use in healthcare environments in the US since the 1970s. However, these have been confined to use of static images, and appear to have been exclusively used the context of clinical rooms in acute hospital situations.

Relevant theories in environmental psychology include Kaplan & Kaplan's "environmental preference matrix" (Kaplan R., Kaplan, S., 1989) (Herzog, T. R. et al, 2011), where positive affective reactions triggered by environments are theorised to be a result of cognitive evaluation as to whether certain information is perceived as being available in a setting. Desirable informational factors are described as *coherence*, *complexity*, *legibility*, and *mystery*. Recent research finds little to support the significance of coherence and legibility factors. Further research intended to support the theory required extensive reanalysis of data in order to demonstrate the significance of the *mystery* factor, which operated only in certain situations (Herzog, T. R. et al, 2011). Subsequent empirical research has demonstrated that response by the autonomic nervous system, measured in terms of skin response (GSR), to specific environmental factors can occur *without* awareness of such stimuli (Ohman, A., Dimberg, U., Esteves, F., 1989); some responses "occur so rapidly that it is difficult to reconcile with a purely 'controlled' cognitive response perspective on human-environment interactions" (Dimberg, 1990) (Ulrich, R. S., et al, 1991). Ulrich's psycho-evolutionary model of environmental preferences suggests that affective response to environment is automatic, and based on an evolved adaptation of preference for landscapes most likely to support survival (Ulrich, 1993). This explains why reaction is rapid and unconscious. Assumed factors on which such unconscious evaluations are made include availability of food, and shelter and safety from predators and the elements. It is believed that these responses are inherited, rather than learned anew by each generation, as ability to recognise such environments immediately and unconsciously confers an evolutionary advantage. Ulrich's framework lists the visual attributes of an environment which result in immediate positive affect as follows:

gross structural properties (e.g., patterns),

depth properties (ground surface and texture)

absence of threats

deflected vista

These overlap to some degree with the predictors of preference the Kaplan & Kaplan model (Kaplan R., Kaplan, S., 1989). There is further evidence to indicate that natural scenes and natural imagery can also support cognitive function. The influence on affect and cognitive function are highly relevant to the design of places for work and educational architecture, and even more so for environments for people with dementia, where stress incurred by cognitive overload is a particular feature. Much of the research regarding support of cognitive function under stress has been carried out in workplace situations.

The body of aesthetics research in relation to fractals suggests that visual or aesthetic preference for natural landscape is largely dictated by the fractal characteristics of those landscapes (Pihel, 2011), though a number of other parameters also affect preference. Research also seeks to establish whether there is a preference for certain types fractal patterns (Hagerhall, C. M., Purcell, T., Taylor, R., 2004). This theory, backed up by a growing body of empirical evidence, suggests that the defining parameter for aesthetic value of natural landscapes is what is referred to as fractal dimension, D , which is effectively a measure of visual complexity, rather than in the factors posited in theories of environmental psychology (Pihel, 2011). There are some correlations between these models regarding the factors contributing to aesthetic preference. The field of fractal mathematics is recent, though arising from earlier mathematical theory. The term “fractal” was first used by Benoit Mandelbrot, from the Latin “fractus” (broken, fractured). Mandelbrot extended the theoretical concept to describe geometric natural patterns (Mandelbrot, 1982). Patterns occurring in nature, such as leaf mosaics, rock formations, or ripples in water, can be described in terms of fractal mathematics, as ever-repeating patterns occurring at different scales: this property is referred to as “self-similarity”. Exact similarity at different scales is present in artificially-generated fractal patterns, while close similarity at different scales is found in naturally-occurring fractals. Fractal dimension, D , is a mathematical parameter which defines the visual complexity of a fractal pattern. A smooth line, which has no fractal structure, has a value of 1, while a completely filled surface

(also with no fractal structure) has a D value of 2. Values for fractal patterns lie between 1 and 2; the closer the value of D is to 2, the more visually complex the fractal pattern. Intriguingly, fractals with a D value within the range 1.3-1.5 have been found to be perceived as the most aesthetically-pleasing (Taylor, R. P. et al, 2005) (Spehar, B. et al, 2003). This preference is not affected by gender or culture. Colour preference, on the other hand, is affected to a degree by cultural symbolism. This preference extends to both artificially-generated and naturally-occurring fractals. Both natural images, which are inherently fractal, and artificial “biophilic” fractals, which are so named as they resemble natural forms, have been the subject of aesthetics research, and of preliminary research on the ability of images with mid-range fractals to reduce stress (Taylor R. P., Sprott, J. C., 2008).

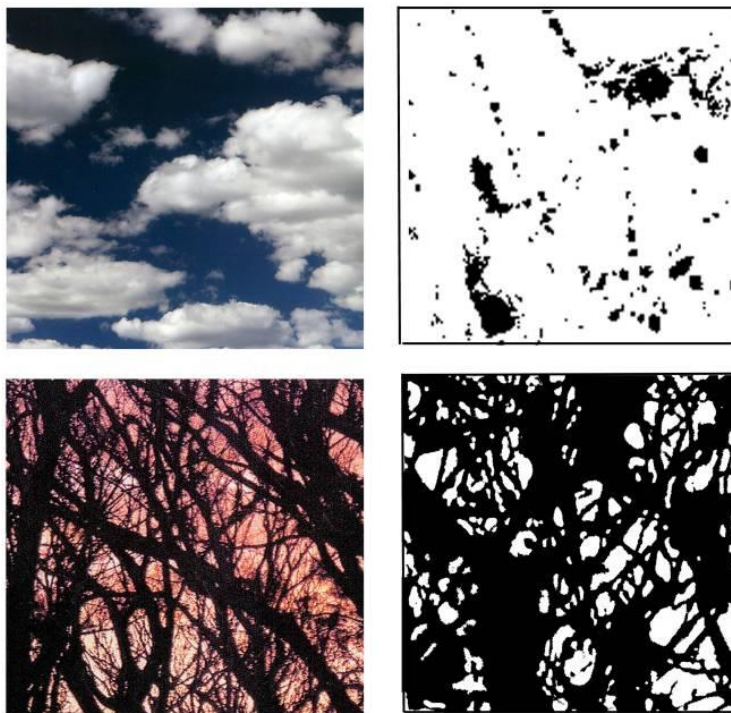


Fig. 1.6 Fractal Patterns

Clockwise from top left:

Clouds $D=1.3$; Jackson Pollock Untitled (1945) $D=1.10$; Jackson Pollock Untitled (1950) $D= 1.89$; A forest $D=1.8$ (Photographs by R.P. Taylor).

This research has also analysed the work of a number of artists, initially that of Jackson Pollock, whose typical dripped patterns possess fractal properties. This style has been dubbed “Fractal Expressionism” by Taylor, distinguishing the ability of an artist/designer to generate fractal patterns from computer-generated fractals. Fractal characteristics can also be observed in architecture, even where it is based on Euclidean form, for example, where an element relates to similar elements at a larger scale. The Modernist movement takes an alternative approach to natural form, by using the building to “frame” natural views, with an often minimalist approach to the design of the building’s interior. This can be less than successful in an urban situation, where the external views framed may have little to offer, and where a user’s experience is largely confined to the interior.

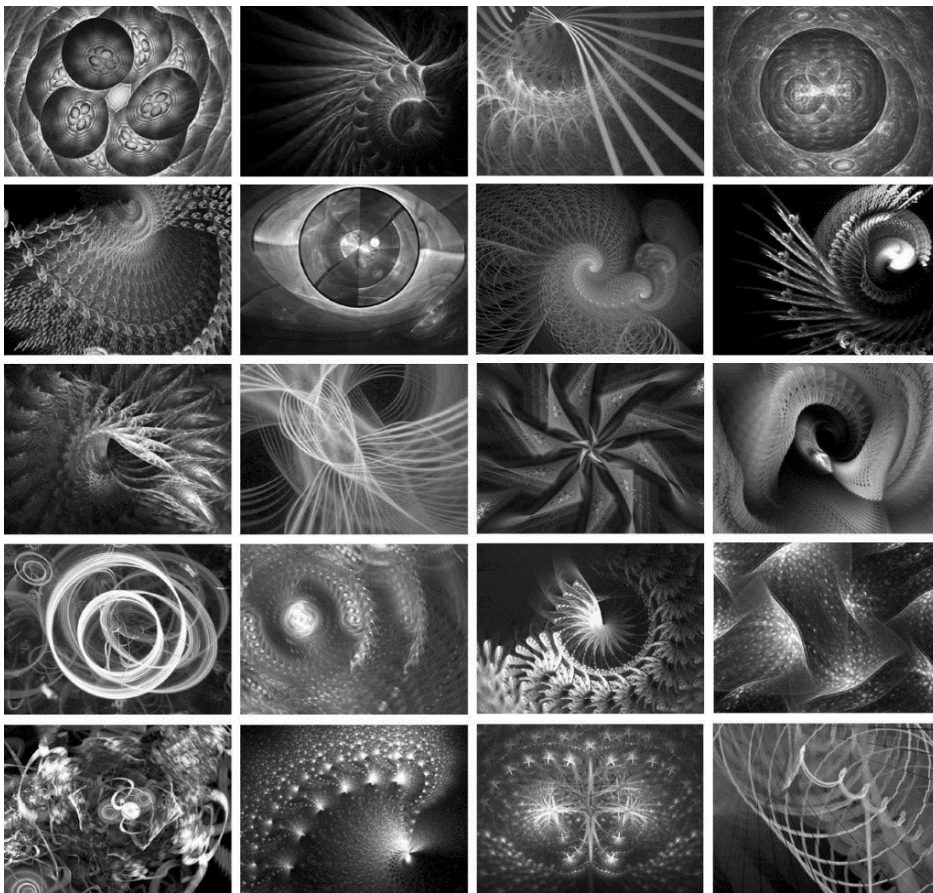


Fig. 1.7 Computer-generated biophilic fractals: *Electric Sheep* (Scott Draves)

Natural pattern	D	Source
<i>Coastlines: Australia, Britain, S. Africa,</i>	1.05-1.25	<i>Mandelbrot, 1977</i>
<i>Coastlines: Norway</i>	1.52	<i>Feder, 1988</i>
<i>Galaxies (modeled)</i>	1.2	<i>Mandelbrot, 1977</i>
<i>Cracks in ductile materials</i>	1.25	<i>Louis et al., 1986</i>
<i>Geothermal rock patterns</i>	1.25-1.55	<i>Campbell, 1993</i>
<i>Woody plants and trees</i>	1.28-1.90	<i>Morse et al., 1985</i>
<i>Waves</i>	1.3	<i>Werner, 1999</i>
<i>Clouds</i>	1.30-1.33	<i>Lovejoy, 1982</i>
<i>Sea Anemone</i>	1.6	<i>Burrough, 2003</i>
<i>Cracks in non-ductile materials</i>	1.68	<i>Skjeltorp & Meakin 1988</i>
<i>Snowflakes (modeled)</i>	1.7	<i>Nittman et al., 1987</i>
<i>Retinal blood vessels</i>	1.7	<i>Family et al., 1989</i>
<i>Bacteria growth pattern</i>	1.7	<i>Matsushita et al., 1993</i>
<i>Electrical discharges</i>	1.75	<i>Niemeyer et al., 1984</i>
<i>Mineral patterns</i>	1.78	<i>Chopard et al., 1991</i>

Fig. 1.8 Fractal Dimensions (D) for Various Natural Fractal Patterns

Adapted from "Perceptual and Physiological Responses to the Visual Complexity of Fractal Patterns"
(Taylor, R. P. et al, 2005)

While the visual information contained in an image may be described using a number of parameters, including luminance, colour, and complexity, the fractal dimension, D , appears to be critical to establishing aesthetic preference. Aks and Sprott theorize that the preference for fractals of mid-range complexity is set by exposure throughout our evolution to natural forms (Aks, D., Sprott, J. C., 1996). Theory in evolutionary psychology suggests that as a species, our brains have evolved the capacity for speech and language (Changizi, 2011), and colour vision (Changizi, 2009) through a process of 'harnessing'. Visual perception and aesthetic preference may have evolved similarly. Human preference for natural images, and the therapeutic benefits that arise from viewing such scenes may therefore arise for more basic and universal reasons than an evolutionary preference for particular landscapes. It is possibly the case that evolutionary preference is less connected to survival needs than to a process of our distant ancestors' brains evolving aesthetic preferences by "harnessing" the sights that surrounded them in their natural

habitat (Changizi, 2009), which invariably contain patterns that are described by fractal equations (Cheung, K. C., Wells, N. M., 2004). The ultimate reason why nature favours fractal patterns is quite simply that they facilitate the most efficient way of storing the greatest quantity of information in the smallest space. So, in nature, not only does form follow function in the most fundamental way, but as a species, we may have evolved to appreciate as “beautiful” or “aesthetically-pleasing” what is ultimately supremely functional. This notion should appeal to architects and designers in other disciplines, and aligns with the concept of “Machine Beauty” (Gelertner, 1998) discussed in Chapter 2.

In relation to stress-relief, empirical research using EEG sensing has shown that viewing fractal images creates an increase in alpha waves in the frontal lobes, and higher beta waves in the parietal lobes, which it is speculated may relate to the idea of “soft fascination” (Hagerhall, C. M. et al, 2008); it begs the question as to whether this is also related to the increase in alpha waves characteristic of the Relaxation Response achieved through meditation (Benson, 1982). While research in relation to fractals, natural landscapes and stress relief/restoration has generally been carried out using images, rather than in real environments, it still produces convincing results. Being in a natural landscape, or observing it directly, provides restorative experiences; research appears to suggest that it is possible to achieve restoration without direct exposure, which is of interest to architects and designers, most particularly in the design of environments for healthcare and work.

An interesting observation may be made on the methodologies used in the testing of natural images for preference in relation to fractal dimension: techniques includes reducing images to grayscale and digitally “de-noising” them to reduce them to their fractal characteristics. The de-noised images very closely resemble pencil sketches. (fig. 1.9) It may be the case that artists and designers (including architects) unconsciously abstract those essential, i.e. fractal qualities through an intuitively reductive approach to what they see before them, in addition to consciously drawing on nature for inspiration. This extends to abstract art: research on the work of Jackson Pollock has demonstrated that his paintings do possess a

fractal dimension, which increases in value in later work, from D values of around 1.1 in earlier work, to more complex fractals with a D value in the region of 1.7 in later paintings (Taylor, R. P. et al, 2011).



Fig. 1.9 Image from “Human Preference and Fractal Dimension”

(The image has been de-noised, reduced to greyscale, and inverted)

The concept of harnessing may also apply to other visual characteristics, such as colour, which it is theorised evolved in primates as a means of identifying emotion in other primates and is also theorised to be the reason for facial hairlessness (Changizi, 2009). Richard Neutra, in “Survival Through Design” refers to an equivalent concept, and also to the temporal qualities of visual perception, the latter frequently left largely unaddressed in architecture: *‘Seeing, like sensing was decisively trained within the natural scene; time is of its essence, although seeing seems to deal only with space’* (Neutra, 1954). It seems likely therefore human aesthetic preferences have evolved perceptually through “harnessing” the natural forms that surround us, which characteristically possess what are described as fractal patterns. If theories of “harnessing” are correct, then it is almost inevitable that architects, designers and artists have, and will continue to draw on the natural environment for inspiration, unconsciously as much as consciously, often utilising

natural forms in an abstract or indirect fashion, in addition to using natural materials, which even on their own, may be of benefit. This last might serve as a defence that much Modernist architecture, while undoubtedly minimalist, may well meet aspirations toward a biophilic architecture, where it draws on a palette of natural materials. Materials such as wood and stone have inherent fractal patterns, so that even a minimalist interior might be said to be “biophilic”.



Fig. 1.10 *The Barcelona Pavilion, interior. Ludwig Mies van der Rohe, 1929*

The canon of Modernist architecture is littered with such examples, from the carefully matched stone cladding of Mies van der Rohe’s Barcelona Pavilion to Neutra’s own work. The theories set out in his seminal book “Survival Through Design”, which were realised in some of his built oeuvre, emphasise the necessity to provide architectural environments which optimise human functioning, by addressing the biological and behavioural needs of human beings. Much of the content of Neutra’s seminal work anticipates far more recent research in other disciplines, including concepts almost identical to “biophilia” and “harnessing”. He also refers to what is now termed “neuroplasticity”, a term coined in 1985 (though

initial research on the topic dates from the 1800s) in describing how physical environment moulds us by experience, through neuronal growth in response to experience of the built environment, as to other stimuli. Both Neutra and, perhaps more surprisingly, Gropius (Gropius, 1962) were greatly concerned with how even the most detailed aspects of architectural design can alter user affect. Though there may be lessons for architecture in environmental psychology, most specifically in taking a more detailed view of human interaction with the built environment, it is far from clear if any specific case needs to be made for the introduction of a “biophilic architecture”, as, other than in the most abstract sense, architecture and design appears to have inevitably taken many of its cues from the environments in which we evolved as a species.

Kaplan’s Attention Restoration Theory (ART) (Kaplan, 2001) is also of considerable relevance in terms of the design of both care settings and workplace settings. ART also provides useful principles for the design of any environmental intervention specifically intended to reduce cognitive stress and promote optimal functioning. ART describes how an individual may become mentally fatigued if *directed attention*, which requires conscious effort, is required for a protracted period of time, in order to complete a cognitive task. Further mental effort may also be required to exclude distractions and delay or inhibit inappropriate emotions while completing the task in question. Kaplan also theorises that, having become mentally fatigued, restoration is then essential in order for the person to continue with tasks requiring directed attention, and that natural environments are most conducive to providing such restorative experience. This contention has been borne out by subsequent research by Kaplan and others. Though much of such research is carried out with workplace environments in mind, all of these factors come to bear to an even greater extent for the person with dementia, as even mundane tasks may become cognitively challenging. ART proposes that a “restorative” environment should have certain essential characteristics, summarised as:

“being away”, that is, being distinct, either physically or conceptually, from the everyday environment;

“fascination”: containing patterns that hold one’s attention effortlessly;

“extent”: having scope and coherence that allow one to remain engaged;

“compatibility”: fitting with and supporting what one wants or is inclined to do.

The first of these, *“being away”*, implies that a setting draws on use of different mental content, which is different to that used when engaged in direct attention, so that the person can *“get away”* from everyday concerns and problems.

“Fascination” implies that the setting has sufficient variability and complexity in content to engage *involuntary attention* without any effort on the part of the observer. It should be such that it does not require the person’s entire attention, this allowing the person to think about other things (which may have had to be inhibited when directed attention is required); this is referred to as *“soft fascination”*, and is to be found in natural settings. Restorative environments which engage involuntary attention also afford the possibility of space for reflection, identified by Corcoran & Gitlin (Corcoran, M., Gitlin, L. N., 1991) as a factor promoting self-actualisation. The third essential characteristic, *“extent”*, requires that the setting (in this case, the room) incorporates enough content and detail to engage and hold interest long enough to allow the person to rest directed attention; Kaplan poetically characterises such settings as *“whole other worlds”*.

Extent is also a characteristic of natural settings, and may exist even where such a setting is small in scale, the example given being the Japanese garden. This may relate to the fractal properties of natural landscape and images, discussed previously, and suggests an interesting link between aesthetic theories of fractals, and ART, as fractals are described as being of themselves fascinating without demanding effort (Joye, 2007). Research has demonstrated a high correlation between fascination and extent, so it is possible that they may not, in fact, represent distinct constructs (Herzog, T. R., Maguire, C. P., Nebel, M. B., 2003) (Han, 2010). The final essential component of a restorative setting is compatibility, which

is achieved if there is a good fit between the person's needs and how they are suggested and supported by the setting, and appears to equate with congruence. Incompatibility may arise when a person attempt to do something that is beyond their ability; defined as such, it may arise frequently in the case of people with dementia, and calls for an approach to environmental design that minimises incompatibility. Incompatibility has been demonstrated to correlate positively with mental fatigue (Herzog, T. R. et al, 2011).



Fig. 1.11 Fascination and extent

The Myth of Multisensory Architecture

“Architecture is illuminated not only by light but by sound as well, in fact it is brought into relief for us by all the senses”

-Richard Neutra, “Survival Through Design”

The term “multisensory architecture” has come to be used to describe specialised environments designed to cater for the needs of users perceived as have special

needs of one sort or another, including cognitive and perceptual impairment. It might thus be casually assumed that these design requirements are specific to people who are at the edges of the norm, but this is emphatically not the case. All architecture is relentlessly multisensory, that it, it is experienced and perceived through all the senses, not only the visual, though too often the latter seems to be, if not the only, then the overwhelmingly dominant concern of architects. We are “entirely a part of the sensible world that we perceive” (Green, 2007) – as well as experiencing that world with our senses, we ourselves have “own textures, sounds and tastes”. The influence of architecture on the person is far deeper and more pervasive than mere visual impact, and furthermore extends over time. As Neutra puts it “millions of sense receptors determine what design can actually do for us”. Even in middle or old age, the brain continues to adapt to its environment. Very recent research demonstrates that environmental enrichment can promote neuroplasticity, and thus alter Alzheimer’s Disease pathology (Petrosini, L. et al, 2009). If this is the case, design of built environment specifically intended for elderly users, inevitably including people with dementia, takes on a critical significance, and all the more so in the light of the types of institutional environments in which elderly people are still most often housed. This is discussed in some detail in Chapter 3. It is only now becoming possible, almost 60 years after the publication of Neutra’s seminal work, to measure, in quantitative terms, exactly how environment affects the human user, both on a short and long-term basis. This is due entirely to developments in ICT, and specifically in relation to sensing of the person.

For all that a “multisensory environment” might be conducive to well-being in specific user-groups, it is equally true to say that all users benefit from environments that address sensory needs, and fail to function optimally in environments which do not. We are not so different from one another. However, the benefits of what is termed “multisensory design” and the detrimental effects of poor design lacking in sensory stimulation are more obvious and immediate in the case of clients with “special needs”. Different aspects of environment operate on

human beings generally, across the board, as does any deficiency in how an environment is designed. In residential environments, as in working environments, detrimental effects may not be apparent in minutes, but may accumulate over weeks or years. It is only very recently that it has been considered that environments for people with dementia might benefit from being “multisensory”. Where recognised, this requirement may still be considered to be met by providing a separate “multisensory” room, rather than by integrating design for all the senses into the built environment in general. As such, this represents a very artificial approach, not consistent with other aspirations towards familiarity and a “homelike” environment.

Even in relation to aesthetics, it can be seen from the evidence that beauty is far more than skin deep: that, as a species, we have evolved neurologically to best process information from the surroundings in which we, as a species, have evolved over millennia. If the environment in which we live departs too far from those in which we evolved, there are all sorts of negative consequences. In building and designing human habitation, we appear to have always sought, as a species, to creatively import aspects of our natural surroundings into the environments we make. Architecture is an immersive medium, for better or worse. At its best, it stimulates, inspires, liberates, and provides refuge, comfort, and security as appropriate to context. At its worst, it confines, curtails, contains, and fails to support optimal human functioning. This happens most culpably where designers fail to consciously address design issues, be they aesthetic, functional or psychosocial.

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Chapter 2

Making the strange familiar:

Architecture, technology and human interaction with architecture

- The symbiosis of technology and design
- Responsive architecture
- Technologies for responsive environments
- Common ground
- An affective responsive environment?

Introduction

Where humans interact with architecture and the built environment, that interaction is often enabled by technologies, specifically where interaction is taken to involve environmental modification. From the earliest times to the present, the use of new technologies has enabled humans to modify their environments, from the simple closing of a shutter to exclude light or contain heat, to complex computer-controlled systems which modify internal environments in a nuanced way. Development and use of new technologies is in itself an inescapable part of the human condition.

Primitive human habitations met little more than what Boyden describes as “survival needs”. (Boyden, 1971) The earliest human modifications of environment were often temporary, and rudimentary in contemporary terms. As cultures evolved, and permanent built structures of greater sophistication emerged, increasing complexity was not only expressed in built form, but also in how architecture consciously facilitates environmental modification, and supports human needs beyond the basic. This chapter will briefly trace how the interrelationship between people, technology and architecture has evolved, leading

to the proposal of a new paradigm for environmental modification, mediated by human-computer interaction, and facilitated by embedded sensor networks.

THE SYMBIOSIS OF TECHNOLOGY AND DESIGN

Reyner Banham, writing in “The architecture of the well-tempered environment”, takes the view that “technological potential often runs ahead of architecture, and that its value and significance to architecture is routinely undervalued if not ignored”. (Banham, 1984) It could equally be argued that potential, fulfilled or otherwise, eternally and of necessity runs ahead of actuality. The view that the architect as a designer of the built environment is essentially a cautious creature when it comes to new technology could equally be countered by the view that on occasion, available technology is the only constraint to a designer’s imagination. While technologies that might potentially be harnessed in an architectural design abound, they may at the time of the design proposal exist only in a prototypical or rudimentary state. Considerable and extensive research and development is often necessary, usually in collaboration with engineering disciplines, to render them practically useful to the architect. Technology in contemporary architecture is very often incorporated in what amounts to prototypical form: it may well be the first time it has been deployed in a specific manner. To quote Helmut Jahn: “every building is a prototype” (Jahn, 2005). The same comment can be applied to individual components of a building. Over the last generation, many novel engineering technologies have been modified before being imported for use in the built environment, or have been developed in a guided manner for specific use in a particular building or design brief. Prototypical technologies and systems may then be re-applied elsewhere, often modified as they are re-used, until they become “mainstream”. The evolution of façade and cladding design over the last 100 years provides a relevant example, moving from simpler functional and aesthetic intention, to highly complex energy-saving façade systems in contemporary architecture. This interdisciplinary specialisation continues to evolve in the direction of responsive façade design, which owes as much as a specialisation to engineering and ICT as it does to architectural design. The distinction here between design and

technology becomes ever more blurred. One feeds off the other: creativity begs the question of technology, while technology frequently demonstrates that creative boundaries can be pushed out almost infinitely. In this sense, architecture and technology exist in what is essentially a symbiotic relationship: new construction technologies beget new architectural forms and languages, while at the same time, the realisation of novel architectural form may require, from the outset, the development or refinement of new technologies in order to realise it. This relationship often operates simultaneously in both directions, with technologies and architectural forms or typologies evolving progressively in a genuinely symbiotic fashion. Even Banham's words bear this out, regarding the architecture and technology of the turn of the last century, where "innovations in the form of large buildings could come some way to meet the environmental technology then available, and together they could offer significant improvements" (Banham, 1984). For millennia, the exploration and incorporation of novel technologies has acted as catalyst for changes in the design zeitgeist, often ushering in the aesthetics of a particular age. The impact on architecture of new technologies is therefore not confined to the merely functional. The aesthetic impact of new technologies can readily be traced historically, ranging from the impact on built form of the use of poured concrete by the Ancient Romans, with its capacity for extended spans, to the current development of responsive facades and bio-inspired architecture. New construction technologies have, each in their turn, influenced the development of both architectural aesthetics and typologies.



Fig. 2.1 The Pantheon (126 AD): the world's largest unreinforced concrete dome

Technologies not only impact on how we make buildings: engineering technologies which are unrelated to the making of the physical form of the building, can also profoundly impact on how buildings are used and perceived. Though the earliest elevators date from Ancient Greece, the development of the powered elevator in the early 1800s, and more particularly the manufacture of the first elevators with a safety braking mechanism in 1853, followed by Otis' first passenger elevator in 1857, profoundly influenced architectural design. The Equitable Life Building, (1870, New York City, Arthur Gilman & Edward H. Kendall) was, at 40m, the tallest building to have been built at that time, and the first office building to have passenger elevators. In baldly functional terms, passenger elevators enabled construction of taller buildings than previously, as there is a limit to the number of floors an average person can be expected to climb unaided. The simultaneous development of structural and mechanical engineering technologies led to the emergence of a new typology: the multi-storey "skyscraper" office building. The first steel-frame "skyscraper" was built in Chicago in 1885 in the shape of the Home Insurance building (William Le Baron Jenney). Louis Sullivan, in "The Tall Office Building Artistically Considered" (Sullivan, 1896) describes the aesthetics of this new typology: *"What is the chief characteristic of the tall office building? It is lofty. It must be tall. The force and power of altitude must be in it, the glory and pride of exaltation must be in it. It must be every inch a proud and soaring thing, rising in sheer exaltation that from bottom to top it is a unit without a single dissenting line."*

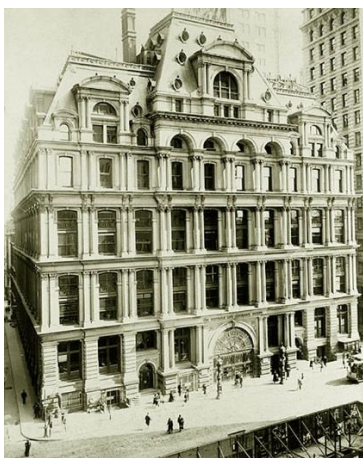
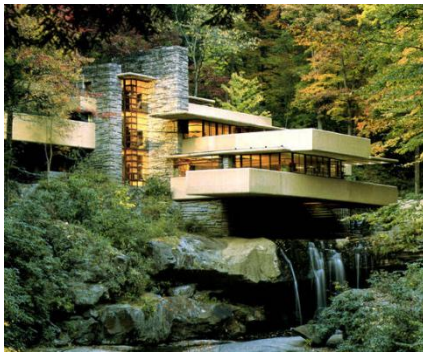


Fig. 2.2 The Equitable Life Building Fig. 2.3 The Home Insurance Building

Without lifts, “skyscrapers” would have been unusable, unthinkable, even. Without tall buildings, lifts would have been of limited functional and commercial value. The same technologies also facilitated far higher densities for urban residential buildings, paving the way for Le Corbusier’s *Unite d’Habitation*, and the revolutionary urban concepts of the *Ville Radieuse*, where high-rise residential construction allowed the ground-plane to be freed up. The use of “pilotis”, one of his “Five Points of Architecture” (Jeanneret, 1923), which allow space to flow uninterrupted, under and around the built form, themselves owe the possibility of their existence to structural engineering.



“Fallingwater”



Notre Dame du Haut



Johnson Wax Building



860-880 Lakeshore Drive

Fig. 2.6 Technology and aesthetics

Other masterworks of Modernism, such as Mies van der Rohe’s *Lakeshore Drive* apartments (1951) or FLW’s *Johnson Wax Administration Building* (1939), would have been physically and formally impossible to achieve without a close and constructive relationship between design and emerging technologies. In Wright’s

work, an intimate understanding of the possibilities of structural engineering in particular, is at the heart of realisation of the quite radical built forms of “Fallingwater”, pushing cantilevers to both physical and aesthetic limits. The elegant dendriform columns of the Johnson Wax building are a manifestation of the freedom of formal expression facilitated by use of reinforced concrete, taken to an apogee in the extreme plasticity of form realised in Le Corbusier’s Notre Dame du Haut at Ronchamp. (Fig. 2.6 above).

The adoption of technologies which are less obviously relevant also has had a profound and lasting impact on architectural design and theory: witness Wright’s suburban theories, and his Usonian homes. The term “Usonian” was used by Wright in place of “American”, and intended to describe the particular New World character of the American landscape and the forms he designed for it. The Usonian house, with its horizontal lines, flowing internal spaces, its connection to the outdoors, and integral car-port, owed nothing to previous architectural form and conventions, but rather more not only to the indigenous landscape, but also to the new engineering technologies pioneered by Wright, (concrete slab foundations and radiant heating systems). But beyond that, its very existence as a suburban typology depended on the new possibilities for habitation created by affordable personal motorised transport: in other words, the advent of the motor-car.



Fig. 2.7 The Usonian House

In the late 19th and 20th century, the invention and rapid adoption of the electric light, and later, the development of air-conditioning systems, allowed for deeper building plans, also pushing up occupancies and urban densities. Conversely, construction of very large buildings brought with it a new set of design challenges to be addressed, both internal and external, ranging from overshadowing, to accommodating the ducting and plant required for the new environmental control systems. The introduction of electric lighting affected usage of buildings to the extent that it has ultimately extended out into how society as a whole functions: a 24-hour society would not have been possible, or perhaps even conceivable, until electric lighting became widespread. With the advent of a 24-hour society, or at least one which continues to operate throughout the hours of darkness, comes an entire set of consequent ills, as well as benefits: the downside includes overwork, stress, disruption of diurnal and seasonal rhythms, and illness as a consequence of Vitamin D deficiency, as people in developed societies spend less and less time out-of-doors. This is perhaps unsurprising: as a species, we have evolved over millions of years in natural settings, and not in the “urban jungle”. What is technically feasible may not coincide with what is ultimately desirable for a society. Any technology may be considered as somewhat of a double-edged sword. It must therefore be borne in mind that any action of the part of the designer or engineer deploying new technologies may have consequences other than the intended.

An interesting consequence of the introduction of widespread electric lighting is the difference in our visual perception of buildings: whereas natural light always downlights, electric light is often used as “uplighting”, completely altering the external appearance of a building. This is an example cited by Malcolm McCullough of how technology “makes the familiar strange” (McCullough, 2005). Information Communication Technology (ICT) can be seen as no more, and no less, than the latest in a succession of technologies to be “absorbed” by architecture; in the case of embedded sensing, that absorption is literal. It is worth noting, in passing, that ICT, in the form of web and mobile technologies has already exerted profound influence on how individuals live their lives, on the potential possibilities for social

interaction, and by extension on the very nature of society itself. We are in the throes of a period of fundamental change in accessibility of information, where web connectivity enables instant trans-global communication, often without the filters imposed by traditional news media, and where remote access to information and knowledge, coupled with networked communication and data systems, allows for novel forms of intellectual collaboration and new work practices. This is manifest at every level, from informal social networking on Twitter and Facebook, to organised intellectual collaboration. The latter is seen not only in business and industry, but in collaborative online gaming such as Minecraft, which involves collaborative virtual design, construction and inhabitation of entire cities. The potential for creative collaboration here seems almost limitless, as more experienced gamers write their own software, or “mods” to create new bespoke virtual objects. By the same token, learning is revolutionised through the capacity of individuals to readily access large volumes of relevant information: this thesis has largely been written from a “connected” kitchen table, not a library desk, supported by online access to reading material and supervisors, and a reasonable connection speed. Ten years ago, it would simply not have been practicable. As an architect and researcher, I need no further convincing: Vive la Revolution! The Internet has rapidly evolved to the point where it provides both social infrastructure, and a virtual space for social interaction. This was, as McCullough points out, hitherto quite literally provided by architecture. Despite the concerns voiced by one of my supervisors regarding “time wasted”, the Internet, in the course of the thesis research, has provided not only a point of access to literature and citations, but far more than that, a source of communication, moral support and informal but productive discussion with other academics.

That such technological developments are not without their downsides has only recently becoming apparent: Just as a technologically-enabled 24-hour society is not always beneficial to humans, so instant accessibility and communication may be no more so, where an instant answer seems to be required to every question. The consequences, which translate into the 21st century scourge of chronic stress and

resulting illness, are only beginning to be fully comprehended. Thus every emerging technology must be treated with a caveat: it has equal potential for good and evil. What transpires is as much a result of how a society chooses to use a technology, as to what the original intentions of the inventor or designer were. Technology, as it is implemented, is very much an expression of the zeitgeist, as much so as art and design. At the beginning of the 21st century time, art, design and technology are becoming inextricably intermingled through the growing ubiquity of ICT in every aspect of life.

Straying further again from technologies which have any physical form with which to influence architecture, we can see how ICT, in the form of computer-aided drafting, with sophisticated 3-D modelling and calculations, has become a commonplace creative tool in the realisation of forms which would too complex to be practicably modelled manually. This has enabled the conceptualisation and realisation of quite extraordinarily novel built forms, and the emergence of digital design methodologies, leading to more fluid design process (Niblock, 2011). The radicalisation of architectural form witnessed over the last generation has taken place for the very simple reason that architects and engineers are now possessed of tools not only to describe and visualise, but to design and construction of forms that would have been nigh-impossible to contemplate previously because they are so complex that it would have taken innumerable man-hours to draught and fabricate them, in the absence digital tools. 3-D printing now allows the possibility of an even more immediate connection between the architect and the building (s)he designs, with production linked directly to digital design. The negative implications are that the same tools have fuelled the recent domination of an architecture where they have become little more than playthings, giving rise to an architecture where superficially formal and aesthetic qualities are everything. Consideration of the intimate relationship between a building and its users (those who inhabit it, rather than those who spectate as passers-by) appears to have dwindled, in many instances, to almost nothing. User-centred design is often perceived as an aside, an intrusion on the vision of the designer.

Though architecture has always mediated interaction between person and environment, there has often been little enough consideration of the details of how that interaction plays out on an ongoing basis. The building itself has often remained a relatively static part of these interactions, unchanged at least in the mind of the architect, after point at which (s)he literally closes the door on a finished project. Human beings have of course always modified their environments, not least because of the inadequacy of what was originally provided, in order to better cope with changing conditions: season, weather, old age, new occupants, new uses. Immediate environmental modification has always been enabled, even in simplest of buildings: doors and windows open, shutters close, awnings are pulled down, fires are lit. As well as recurring modification, users have also modified buildings in other, sometimes permanent ways. When the architect departs, curtains are hung on picture-windows, rugs laid on pristine floors, doors wedged open, notices sellotaped to walls and fixtures, furniture hauled about, rooms repainted. Building services technologies have become part of the mediation between user and built environment, allowing mechanical and automatic modification of environment for human comfort, essential in large buildings. This particular relationship between architecture and technology has become increasingly important in the design of sustainable architecture, demanding ever more nuanced environmental controls. These are enabled, with the advent of ICT, to respond to changing environmental conditions and occupancy without direct user intervention. It is not always possible to predict all outcomes in advance; technology may not be market-ready, and thus responsive systems, as constructed, may only offer environmental modification within a framework limited by the available technology. Thus architecture provides a valuable real life testing-ground for new technologies, or new uses of technology, provided that outcomes are monitored after occupancy, and used to inform future design. It is not an understatement to say that the influence of ICT on built form has been profound and lasting, not only by virtue of use of CAD and digital fabrication, but also in terms of enabling not just environmental adaptability, but automated and orchestrated adaptation and responsiveness, of a scale and variety hitherto unfeasible.

Architecture, both as a profession, and as a discipline, stands in a unique and privileged position between the arts and the sciences. It is long accepted that the fruits of innovation in technical disciplines such as engineering become part of the architect's armoury. While there will always be a perceived tension in architecture between the aesthetic and the functional, both in technology and brief, what also fascinates is the possibility that where good design is defined as something more the aesthetically-pleasing, functional and aesthetic considerations may converge, through the medium of technology deployed in design. Architecture might also be seen as fulfilling the role of the "technology gate-keeper", as it becomes the locale where people interact with novel technologies, and where those technologies themselves enable human-environment interaction.

RESPONSIVE ARCHITECTURE

The term "responsive architecture" was coined by Nicolas Negroponte, and the Architecture Machine Group at MIT, who conceived the notion in the late 1960s, when application of cybernetics to architecture was first used to explore spatial design issues (Negroponte, 1975). Negroponte proposed responsive architecture as the natural product of the integration of computing power into built spaces and structures, and that better-performing, more rational buildings are the anticipated result: in short, a "well-tempered environment" further enabled by computing. He also extends this relationship between architecture and computing to include the concepts of recognition, intention, contextual variation, and meaning into computing, and the successful integration of ICT systems into architecture. While responsive architecture is a subset of adaptive architecture, adaptation does not of itself imply responsivity.

In responsive architecture, enhanced functionality is to be achieved by means of the building fabric, or components of the fabric, being rendered both responsive to environmental context, and capable of reacting appropriately to contextual variation. Environmental sensing is an implicit necessity for this type of interaction;

that is, the built environment must be equipped with sensors which are part of the building fabric, or conceivably, are embedded in objects in the built space, for example, in furniture. Examples of responsive architecture range from those where the focus is on environmental management and energy-efficiency, for example, through design of responsive facades, and at the other end of the spectrum, buildings where responsivity is couched in visual terms, and managed creatively by considered mediation of environmental input. What both approaches have in common in many cases is a fundamental dependence on ICT systems to manage environmental inputs and related building response. A simple and common example of responsivity is the use of temperature-sensitive ventilation grilles, which open automatically when a specified internal temperature, registered by a thermostat, is reached. Considerably more complex systems are already in use in adaptive facades. One of the first responsive facades is that of the Institut du Monde Arabe (Jean Nouvel, *Fig. 2.8*), where intricate screens, composed of moving metal parts resembling the focussing mechanism in a camera, respond to external light intensity. The screens also refer aesthetically to the intricate “mashrabiya” screens used in Arabic architecture. Façade systems have since increased enormously in sophistication and functionality, aided by advances in programming, which facilitate more subtle response to multiple variables. Direction and intensity of sunlight, wind direction and precipitation may be used singly or collectively to mediate the relationship between the internal and external environments. Many responsive solutions are fascinating in their technical complexity, and in the aesthetic outcomes predicated by this. In responsive façade design, while the use of a repeat element may at first appear to reduce visual complexity, adaptivity at the same time sets up the potential for a constantly-shifting aesthetic, viewed on the scale of the entire building, as a façade alters subtly in appearance over the course of a day, and from day to day, or season to season. The inclusion of multiple and repeating kinetic elements also opens up endless possibilities for the detailed design of such elements, which supports repetition of form both within that element, and also at the scales of an entire storey, floor or building. These relationships might be designed proportionally, much in the fashion in which the

entire façade of a typical Georgian house can be derived from a single dimension of any given element.



Fig. 2.8 Institut du Monde Arabe (Jean Nouvel, 1987)

The kinetic façade of the thematic pavilion for Expo Korea 2012 (SOMA Architecture, *Fig. 2.9*) utilises bio-inspired forms in the design of the shading lamellae. While the ultimate rationale behind the use of such forms may be functional, and engineering-based, they also possess an inherent aesthetic appeal. The formal simplicity of the “blades” which shade the façade of the pavilion belies the fact that they are derived from rigorous functional and mathematical analysis of natural form in order to exploit its efficiencies in the manmade environment.

In the natural world, function and aesthetics become truly inseparable: what we, as human observers, perceive to be perfectly beautiful is no more and no less than an expression of perfect contextualised functionality on the part of the organism. If we seem to base a good part of aesthetic preference on how we have evolved neurologically in response to natural environments, this must also imply that we are “pre-programmed” as a species to perceive and experience the physical expression of function in natural forms as “aesthetically-pleasing”. As a species, we are inexorably drawn to forms, sounds and imagery that emulate, even in a very remote, intellectually complex, or “designed” fashion, the fractal nature of our

evolutionary context. This concept resonates perfectly with that of “machine beauty”. “Form ever follows function” (Sullivan, 1896), and in the most profound sense. In fact, the non-linear/non-solid nature of the fractal provides the most efficient format for encoding the maximum amount of information in physical format. In that case, an innate “appreciation” of functionality and efficiency, whose apogee is reached in natural form, may constitute an inescapable part of our human makeup, embedded in aesthetic preference. Thus a manmade design, which approaches perfection in the eye of the beholder, may be no less and no more than a design where functionality and aesthetics are effectively indivisible: where the one becomes the other. Frank Lloyd Wright commented that “form and function should be one, joined in a spiritual union”; technology is the mediator here.



Fig. 2.9 Expo 2012 Keosu: Thematic Pavilion One Ocean SOMA Architecture

This new potential to orchestrate for infinite and ongoing variability draws the dimension of time into the domain of architecture, allowing the designer to exploit it aesthetically. There is something very intuitive and quite beautiful about this approach, which reflects context, mimicking, as it does, the infinite variety and mutability of a natural landscape, and relating in a very direct, if mediated fashion to the element and the seasons. Thus, responsive architecture can take on a temporal aspect. Responsive facades are at the same time highly mechanized, and

highly organic in terms of how that response is made visually manifest. That manifestation is orchestrated by the detail design of facade elements and their incorporation into the façade. This might be considered a less self-conscious and more intuitive intervention than that of the building-size art installations. The external appearance is effectively constantly “intuited” from the surrounding context. Here, there is no space between design and technology.

Computer-based Building Management Systems (BMS) which monitor and control building services, such as heating and lighting in internal environments, have been in use for several decades now, and have moved towards progressively more automated control. A BMS utilises sensors to collect environmental information. While a system may be aware of all sensed data, the processing of data, and resulting actuation, is often localised, precisely because localised response is required in order to address context-specific needs, the relevant context being the individual room in question. Systems being researched include management of internal lighting based on room occupancies, where users are tracked using RFID tagging. Here, sustainability through reduction in energy consumption is the motivation.

Though Negroponte’s focus was functional and technical, some subsequent exploration has envisioned responsivity in purely aesthetic terms, creating interactive visual installations at an architectural scale, which respond aesthetically, rather than functionally, to contextual data. Enabled by ICT, aesthetic response is mediated creatively, often in real-time. It has no functional component, and is often overlaid onto a pre-existing architectural framework as an art installation. Some installations are small-scale, others, such as Jason Bruges Studio’s “DataCloud”, at the Eircom Headquarters in Dublin, are at the scale of the whole building. “DataCloud” renders the entire envelope of the Eircom building responsive, visualising patterns of use of elements of network traffic, such as email or e-commerce. The response takes place in real-time. Here, data is not sensed from

context, though it is in much of the studio's work, including "Shortcut" (Dover Yard, London, 2010), a site-specific responsive lighting installation, which reflects recent movement of people through an existing urban pedestrian route. The approach here is arguably more architectural than in Connolly-Cleary's "Pourquoi-pas toi?", a room-scale installation which also generates visual response to sensed movement. While the patterns cast on the wall in "Shortcut" are less visually dramatic, they are very much designed with context in mind. Denis Connolly and Anne Cleary, artists both trained as architects, and working largely with video and film media, have produced a number of room-sized installations, where data is processed in real-time, with a slight time-lag in response. In "Pourquoi-pas toi" the user/observer becomes very much an integral and intended part of the final aesthetic outcome, which then fully constitutes an "open work" in the manner described by Eco. It is still, however, an overlay on the architectural fabric, and not place-specific. In *Pourquoi pas Toi*, aesthetic response is also specific to, and generated by, the person.



Fig. 2.10 *Pourquoi Pas Toi?* (Connolly-Cleary)



Fig. 2.11 Data Cloud (Jason Bruges Studio)



Fig. 2.12 Shortcut (Jason Bruges Studio)

The work of both Jason Bruges and Connolly Cleary hints at similar possibilities for internal architectural environments. The prospect of spaces where aesthetics are constantly fluid and governed by human interaction, guided by embedded systems, intrigues. There are as many design outcomes as users, designers, contexts, and above all, interactions. There is also the implicit possibility of user engagement with a complete designed in environment in an ongoing and symbiotic relationship where user action alters environment, and where environmental change in turn operates on the user. Other explorations in responsive architecture include forays into kinetic responsivity, including “intelligent kinetic systems” defined by MIT’s Kinetic Design Group as “architectural spaces and objects that can physically re-configure themselves to meet changing needs.” Holger Schnadelbach’s ExoBuilding

takes yet another approach, exploring kinetic response to bio-sensing, and mapping physiological response onto kinetic adaptation. The movement of the fabric “tent”, which is actuated by processed data of the occupant’s sensed breathing, has a “biofeedback” impact on the user, whose respiration rate alters so as to suggest that the experience is de-stressing, for about half of all users. (Schnadelbach, 2011) (Schnadelbach H, 2012). In the MyRoom proposal, such a de-stressing effect is consciously sought, as a component of a therapeutic responsive environment.

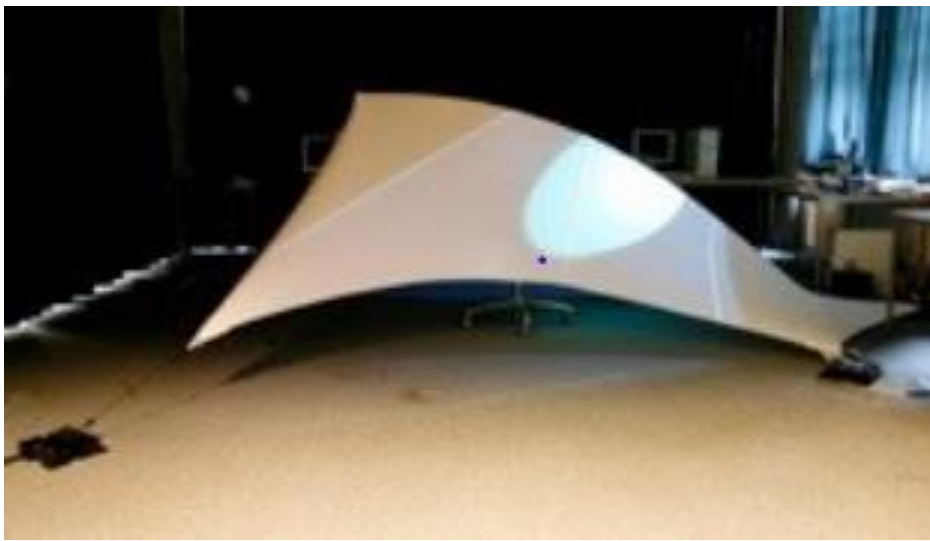


Fig. 2.12 *ExoBuilding*

Schnadelbach has also developed a conceptual framework for adaptive architecture (Schnadelbach, 2010), identifying motivations and drivers as *cultural, societal, organisational*, and *communication*. In this thesis, considerations of user-centredness, within an overall socio-cultural context of a rapidly-ageing society, is a prime motivator. Response to contextualised user data is envisaged, with the desired effect of facilitating environmental fit for a given individual in her own personal life-space.

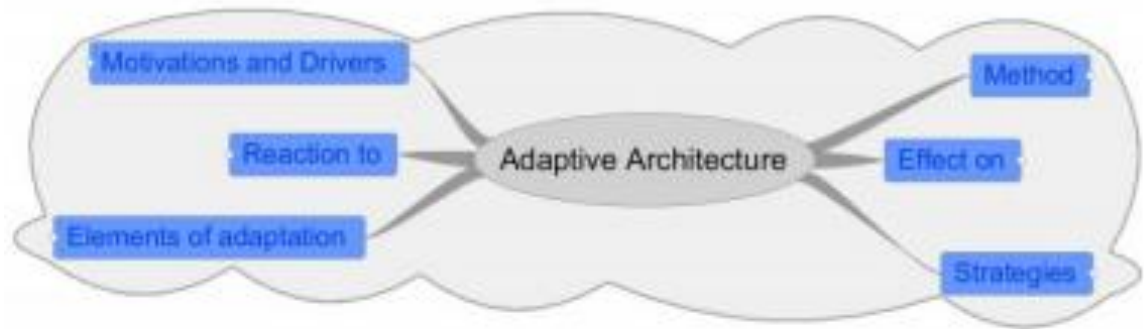


Figure 1 Top level framework categories

Fig. 2.13 Top-level framework categories for Adaptive Architecture (Schnadelbach, 2010)

Intelligent buildings also fall under the general description of “responsive architecture”, but while in keeping with the Negroponte’s aims of producing more streamlined and efficient function, much research in this area as yet seen as being within the remit of the ICT engineer, and lacking in any overall architectural design intent.

Writing on responsive architecture, Daniel Grünkranz refers to “the sometimes tense relationship between phenomenology and technology..... shown in a missing acceptance for the nature of technology and its development as a fact of human endeavour”. (Grünkranz, 2009) As architecture has made other technologies its own, it will also, almost inevitably come to fully utilise ICT as an integral aspect. This may be subject to a need for sensing technologies to become sufficiently evolved for them to be used creatively in a seamless fashion, or developed hand-in-hand with specific design intentions. This is happening at the present time, and denotes a “coming-of-age of calm technology” predicted by Mark Weiser and John Seely Brown (Weiser, M., Seely Brown, J., 1996). Weiser, an ICT visionary, is also widely regarded as the father of “ubiquitous computing”, which is a fundamental requirement for responsive architecture.

TECHNOLOGIES FOR RESPONSIVE ENVIRONMENTS

Ubiquitous Computing and intelligent systems

Ubiquitous Computing, (UbiComp), refers to the embedment of computing systems, sensors and devices in objects or in physical fabric, so that technology recedes and becomes a part of normal life. It implies intuitive use, and a recession of technology into the background. Ubiquitous computing is also referred to as “pervasive computing”, and more colloquially as “everyware” (Greenfield, 2006).

A holistic approach to the design of a system architecture for UbiComp (where “architecture” is used in the ICT sense) involves *smart devices*, *smart environments* and *smart interaction*, referred to as a “Smart DEI” framework (Poslad, 2009).

UbiComp systems are further defined as being internally distributed, autonomous, context-aware, intelligent, and involving intelligent Human-Computer Interaction (iHCI). Distribution implies that though the system involves multiple devices, rather than a single computer, it nonetheless operates cohesively.

A responsive architecture which aspires to being person-centred will require all three components of a Smart DEI framework, (smart devices, environments and interactions) up to and including where the architectural space itself becomes the “device”, with the fabric of the built environment providing the user interface. A UbiComp system which operates a responsive environment must interact externally largely through human-computer interaction (HCI) and computer–physical interaction (CPI) rather than virtually or computer-to-computer (C2C). An extended model of Ubiquitous Computing requires systems which are capable of multiple dynamic actions/interactions, governed by intelligent decision-making and organisational interaction. This of itself implies artificial intelligence.

While smart interactions focus on user context, smart environments are concerned more with physical context. Sensors are required to provide information to the system about both user and physical context, so that the system may effectively

manage interactions between user and environment. An event in the physical context might be, for example, a change in lighting levels or temperature; in a user, it might be a pattern of repeated movement, for example in carrying out a specific task. Sensors are networked, enabling data to be interpreted collectively, and also to allow sensors to collaborate locally, including in order to contextualise user data. User data, for example, from a wearable accelerometer, can tell us that the user is moving. If that data is contextualised, the system can determine what the purpose of that movement is, and respond accordingly. In this example, the system might use contextualised movement information to tell where a person is within a space, and to infer what they are doing. The contextualised data might then be used, say, to switch on a desk lamp in response to the action of a person sitting down at the desk. In responsive architecture, contextualisation of sensed data is critical. A fully responsive architecture in the sense envisaged by Negroponte will of necessity require multiple interactions both in response to environmental context and between person and environment, and a dynamic and intelligent system to manage sensors, devices, software, middleware, platforms, applications and interactions on an ongoing basis. All sensed data in such a system must be processed, in order to acquire information that has useful meaning. System intelligence is also facilitated by “machine learning” where a system is programmed not only to record data, but to assess, interpret and respond autonomously to changes in condition, without further human input, in short, to “learn” from inputted data, to enable intelligent decision-making. In a responsive environment, actuation initiated by the system will be in response to user and contextual data. Machine learning is in many ways the “Holy Grail” of computing; it requires extremely complex programming, and is still in its infancy in terms of practicability. It remains, however, a prerequisite for system intelligence.

To be efficient in use, it is accepted that a balance is required between complete system autonomy, and human direction. It would be difficult to describe as “person-centred” a responsive architecture without some degree of direct human intervention, regardless of whether machine learning ever develops to the extent

that no such intervention is required for a system to perform optimally. An implicit requirement for behavioural choice and control as components in optimising environmental fit, in particular for certain users, would suggest otherwise. However, on that note, evidence from a post-occupancy evaluation (POE) of the Maggie's Centre at Dundee (Stevenson, F., Humphris, D., 2007) suggests that users were not unduly perturbed about loss of personal control of environmental conditions in the building, even where they required adjustment (e.g. to compensate for glare, overheating). This is perhaps on the assumption that a carer/staff member would intervene to optimise them. On that basis, a Building Management System (BMS), which intelligently and unobtrusively manages local internal environmental conditions, might not represent a loss of control or choice. While this is of particular benefit in the case of user with physical or cognitive impairment, it may prove no less attractive an option in many other built contexts. Control, or a perception of personal control, might be cultivated through offering the option of direct intervention.

Debate continues as to how intelligent systems might best be designed. One approach is that all parts of an intelligent system, sensors included, should be able to process data, so that intelligence is *distributed* within the system. A significant advantage of this approach is that an intelligent local sensor can be designed to relay only information regarding a significant change in state, a significant event, or a pattern of events, to the system, rather than relaying all data, so that the system is not overwhelmed with useless data. In the envisaged scenario, which involves affective computing in management of actuation of devices and applications, contextualisation of data is also critical, as it will be used to infer ongoing user status in order to manage real-time response.

Affective Computing

Affective computing (Picard, 1997) can be defined as "Human-computer interaction in which a device has the ability to detect and appropriately respond to its user's

emotions and other stimuli". The term implies that systems or devices are designed so as to become empathetic to human *affect*, or emotion. The goal is to increase usability of systems, but also to inform decision-making, by rendering it more efficient. This begins to align with Don Norman's views on "emotional design" (Norman, 2005), which is that designed objects are easier to use when people develop a relationship with them, in short, when they *like* using them.

Sensing of the person is necessary in order to infer affect, either through sensing of bio-signals such as heart rate (HR), and galvanic skin resistance (GSR), or through other, more indirect means, which include video analysis of facial expression or movement patterns, or analysis of vocal intonation. HR and GSR, in particular, constitute secondary indications of hormonal and biochemical changes involved in emotion, regarded as proxies for affect, but are obviously more readily and less intrusively measured. Again, what is required is the useful data, not all of the data (for example, the primary information on biochemical and hormonal changes). So, while it would be impracticable, at least with currently available technologies, to continuously measure those fluctuations directly, it is practicable to observe and measure other changes, which begin to give us critical information about the person's psychological state. In many ways this resembles a design approach: it is not a perfect solution, but the "perfect" solution is unobtainable in the real world, at least currently, and is limited by available technologies. At the same time it is possible to imagine more sophisticated biosensors that will provide precise information about the biochemical changes that underlie the changes we are able to observe, but they may ultimately prove unnecessary in the particular context of responsive architecture. GSR is familiar to the layman from its use in polygraphs (lie detectors), and is usually measured by placing electrodes on the fingertips. The electrodes measure changes in the resistance of the skin to transmission of electrical current when stress levels are raised, where resistance decreases due to an increase in sweating. While electroencephalography (EEG) data can give very accurate information on brain activity, until recently the sensing apparatus had changed little in over 50 years, and was entirely unsuitable for some subject groups,

especially for persons with dementia. Recent development of portable headsets, which can record EEG activity (the Emotiv EPOC) for later analysis has allowed research relying on sensing of EEG to finally move out of the lab and into live environments, including being used to gauge participant reaction to a variety of urban environments. (Aspinall, P., et al, 2013). This development has exciting implications for research in many areas, including that of human perception of designed environments. When using EEG data, “artifacts” i.e. data from brain activity from all other sources, must be extracted in order to have usable data. The next step is development of portable EEG apparatus which can relay real-time data. Even in this case, such a device would not be suitable for use in a long-term residential or care scenario.

In certain situations, change in affect is readily detected through certain bio-sensing, as in the case of children with ASD whose heart-rate (HR) increases significantly prior to a temper tantrum, though there is no change in facial expressions, as is typical in ASD. In this case the ability to detect such atypical changes in HR might serve not only as an “early warning” for carers or teachers, but also be utilised as a self-management tool for the subjects. The proposal to use affective computing for such research was initially made at MIT Media Lab. Affectiva, a company which grew out of collaborative research at the Media Lab, has subsequently produced a wristband sensor (the Q sensor) based on sensing of GSR (rather than HR). It is currently being used in research on children with Autism Spectrum Disorders (ASD), to gauge how they react to specific therapeutic intervention, on research into adolescent anxiety, and on subjects with sensory processing disorder and mental disability. It is also being piloted in usability research for devices.

There are many constraints which face the development of a real-life prototype of the environment described in subsequent chapters. The current lack of suitable, and affordable, sensors, and sufficiently evolved sensing methods, such as to readily facilitate continuous unobtrusive sensing in a live environment, is a significant obstacle. This is critical where there is a requirement for longitudinal

research, for which sensing methods need to recede almost completely into the physical context. However, the description of a hypothetical responsive environment may prove of value as a roadmap to guide other research into development of new technologies, or appropriate extension of existing technologies in order to meet previously unidentified client needs. This might conceivably extend to materials research, in order to provide sensor substrates, to support design of sensors which can be deployed completely unobtrusively. In this sense the architect-designer is well-placed to become a technology gatekeeper in a very proactive way.

Multimodal sensing, i.e. simultaneous sensing of more than one bio-signal, potentially offers a means to identify atypical changes using only one of the signals sensed, once patterns have been established and corroborated through supplementary sensing methods. For example use of GSR and temperature sensing together allows discounting of changes in GSR that are not associated with increased stress, but, for example, result from a change in body temperature. So multimodal sensing allows the elimination of superfluous data by comparison of sensed data, and may permit use of one type of sensing only in subsequent research of usage. The goal remains the facilitation of real-time sensing which is as unobtrusive as a possible. In this particular context, less is definitely more.

It is reasonable therefore to propose that an entire system might be programmed to infer and respond to affect. As well as HR and GSR, affect can be inferred from facial expression, based on a general consensus among theorists that there is a relatively small set of “basic” human emotions: fear, anger, sadness, and joy are the most commonly identified, with disgust and surprise the next two most common, after which theories diverge (Ortony, A., Terence, T., 1990). Much pioneering work in relation to inferring affect has been carried out in MIT, including research into inference of cognitive-affective state from facial video. (Baltrusaitas T., et al, 2011) This operates on much the same basis that we as a species do, in inferring

emotional state from facial expression, and also from skin tone, depending on blood volume, which varies with HR and blood pressure. Facial skin tone might be mapped back onto affect. There are caveats relating to specific approaches to inferring affect: not all methods are suitable for use with all subject groups of contexts. For example, facial video analysis will have little or no value in a subject group which does not express emotion well facially, such as occurs in ASD.

While it may be perceived as a more “architectural” solution to rely only on sensing embedded in the built environment, wearable sensors may be required either as an intermediate or permanent component of an affective responsive environment. Any solution is likely to be context-specific, and may be a both/and, rather than an either/or solution, that wilfully excludes one or other approach. It may also be dependent at any given time on technological progress. There are particular ethical issues in relation to the physical format of wearable sensors for real-time sensing of a vulnerable user. Even the most sophisticated of available bio-signal sensors, such as the Affectiva sensor, which originates from research at MIT, may be unsuitable for a use with people with dementia, as from mid-stage on, the sensor itself is likely, as an alien object, to constitute a source of stress for the user, which is particularly inappropriate in the context of dementia care. For any user in a real-time setting, the term “wristwatch-type sensor” begs the question as to whether the user is required to forego the familiar technology of the wristwatch in order to wear the sensor, which may be regarded as a nuisance at best. At some point, miniaturisation may permit the addition of sensing capacity to a conventional wristwatch. It would seem that architecturally-embedded solutions with little or no reliance on wearables may be appropriate for users in residential or care settings. The caveat is that wearables may be required, if only on an interim basis, to give rounded and continuous picture of affect.

COMMON GROUND

While, at first glance, the disciplines of architecture and information technology might appear to be at some remove from one another, an examination of the literature uncovers numerous concepts and ideals which are held in common, some with shared roots. One of these is the concept of minimalism. While minimalism is regarded a significant movement in 20th century art, including music, there is no consensus in the arts as to exactly what minimalism means. However, there are five identifiable concepts of minimalism which repeatedly surface in literature on minimalism in the arts. These are: minimality of *means*, of *meaning*, of *structure*, the implicit involvement of the recipient in the production of the end result, and, lastly, use of *pattern*. (Obendorf, 2009) Use of pattern, in the form of a repeated note, phrase, or cadence, characterises much minimalist music, and is a feature of the work of Arvo Part, including in the popular “Spiegel im Spiegel”. Other minimalist music, where the performer becomes an intrinsic part of the performance, has the same inherent characteristics as an “Open Work”. Current musical research includes compositions where the use of bio-sensing allows audience reaction to become part of the ongoing performance. (Knapp R. B., Lyon, E., 2011) In this proposal for a responsive architecture, the user comes to occupy a similar position as the “performer”, in a constant and ever-changing interaction with the built fabric, which in turn informs the aesthetic outcome, as much as the functional.

Hartmut Obendorf, in “Minimalism: Designing Simplicity” has identified four aspects of minimalism for interaction design, which draw on these “common qualities of the minimal” (Obendorf, 2009). Obendorf describes the first two qualities, functionalism and structuralism, as being “concrete”. They relate to tools for interaction. The latter two qualities relate to the context, and are transient. The terms “architectural” and “structural”, as used in this instance, do not relate to the inner structure of a software system, where they constitute commonly used ICT terms, but are used more in the sense in which they are used by architects. Here, they refer to the design of an interface, and accessibility of function. Examples of architectural minimalism in interaction design include devices where the

combination of several simple tools simplifies handling of complex tasks, e.g. using iPod Shuffle with iTunes on a laptop.

<i>Functional</i>	<i>TOOLS</i>
<i>Structural</i>	<i>-concrete aspects-use of tool</i>
<i>Architectural</i>	<i>CONTEXT</i>
<i>Compositional</i>	<i>-transient-accessibility of function</i>

Fig. 2.14 Common qualities of the minimal (adapted from *Minimalism: Designing Simplicity*)
(Obendorf, 2009)

The use of pattern, a recurring concept in minimalism in art, becomes part of the further MyRoom thesis proposal for a responsive environment, on two levels. The first is the use of natural patterns in a very specific manner in the proposal for a visual application, which forms part of a responsive personal life-space. The second is in the manner in which the implicit involvement of the user in the eventual aesthetic outcome is imagined. As interaction evolves over time in an intelligent responsive environment, it will inevitably generate responses which reflect repeated patterns of use: diurnal, seasonal, and personal. These may be expressed creatively, through processing sensed data in visual or kinetic form. This approach incorporates an element of feedback response, closing the circle between user and environment, which is common in contemporary approaches to designing responsive environments (Bullivant, 2006). Biofeedback, manifested visually or kinetically under specific conditions, as in ExoBuilding, might then be seen as a desirable, and even a defining characteristic of responsive architecture actuated by personal bio-data.

A person-centred responsive architecture, and in particular, one which includes adaptation based on affective response, of its nature implies a quintessentially minimalist approach to interaction design. Nor should minimalism be confused with simplicity: a minimalist approach to interaction design may require vastly complex

software. Simplicity does not imply a simplistic approach. Where simplicity must predominate is at the user interface, for reasons of usability. Minimalism in design is too often expressed as an absence - for example, of decoration- rather than a refinement. The architect must therefore continuously query when is less more, and when is it simply less. This applies equally, and critically, in successful interaction design. While minimalism in architecture almost invariably tends towards reduction, the interaction designer must constantly query what appropriate targets for reduction are: system, interface, content, and so on.

Concepts of aesthetic quality and elegance are also not confined to creative disciplines, but recur in ICT, mathematics and engineering, which may be to the surprise of many creative practitioners, architects included. There is an ongoing, and often controversial debate in applied disciplines regarding the relationship between usefulness and beauty, and to what extent aesthetics impact on usability. David Gelertner, in his book *Machine Beauty* (Gelertner, 1998), writes of the significance of elegance in design in engineering and in ICT systems, defining Machine Beauty as “the marriage of simplicity and power”. He very eloquently refers to our sense of beauty as something near-absolute, “a tuning fork in the brain that hums when we stumble on something beautiful”.

Human-computer interaction (HCI) customarily uses measures like efficacy and efficiency as measures of quality, but makes no reference to aesthetic qualities. Beauty can be nonetheless be used as a measure of quality, (Gelertner, 1998) for example in the design of a tool, or an interaction. Gelernter and after him, Obendorf, stress that machine beauty is not merely power and simplicity in isolation. While ICT does not intentionally create systems and interactions which are over-complex, this is not infrequently the outcome where the technology, rather than the user, is placed at the centre of the model for interaction. Affective computing and machine learning can both be used as tools for addressing issues of “user-friendliness”, as can the design of an entire system. The design of a responsive system for use in the built environment might well produce intentionally

simple interfaces, but will be the result of a complex process, including design of software, hardware, systems, and potentially of materials, involving iterative prototyping and testing. In this last, it closely resembles the architectural design process, where the original design concept is compared with the proposed solution at intervals throughout the design process, and revised or refined as necessary. As algorithms form the core of software, an efficient application or system requires powerful algorithms, which enable the program and ultimately the system to run efficiently and without using too much memory. When designing a responsive system which manages, among other characteristics, the aesthetics of a room environment, beauty runs more than skin deep, and matters fundamentally at all scales of design.

While architects may be frequently guilty of neglecting concerns of usability in favour of the aesthetic, Gelertner comments that technologists, reflexively, tend to reject the idea of beauty. Software designers and engineers often seem to recoil equally from suggestions or proposals that have any hint of the aesthetic or the intuitive despite an acknowledgement in the field that the best software and systems embody simplicity, power and elegance, the characteristics of “machine beauty”. Those characteristics have very much in common with long-held notions of the aesthetic in architecture, harking back to the Palladian principles of “commodity, firmness and delight”. The notion of deep beauty resonates also with aesthetic and intellectual notions of minimalism. In the words of Albert Einstein, things should be “as simple as can be but no simpler”. As Don Norman puts it: “simplicity is highly overrated” (Norman, 2007); true minimalism in design is an entirely other concept.

Gelertner also correctly identifies a general propensity to treat the artist and the scientist as if they were entirely separate beings. This distinction is not only artificial, but is very much evidenced as a fallacy in the architectural profession, which sits on the divide between the arts and the sciences, and where a firm grasp

of technology is essential to the realisation of the best architecture. Notions of the aesthetic or of beauty abound in mathematics, itself a cornerstone of ICT, so it is a matter of little surprise that much credible aesthetics research is actually carried out by mathematicians. Hardy, in “A Mathematician’s Apology” (Hardy, 1940), argues that aesthetic considerations alone are enough to justify the study of pure maths. In the time since *Machine Beauty* was published in 1998, the emergence of more user-friendly digital technologies has encouraged many artists to cross the “digital divide”, to produce work in “new media”. ICT has also facilitated the emergence of what is referred to as “intermedia”, where different art forms such as music and visual art, intermingle. Ted Nelson goes so far as to say that “the integration of software cannot be achieved by a committee... It must be controlled by dictatorial artists” (Nelson, 1990). This particular proclamation might have its attractions for the architect, as it might be taken to imply that interaction design in architecture must inevitably consolidate the architect in her traditional position of orchestrating the end result.

It would appear therefore that there are significant commonalities between what are often conceived of as completely separate spheres, that is, those of ICT/software design, and that of the aesthetic as manifest in art, design and architecture; it would rather seem to depend on how one chooses to look at it. The motto of the Bauhaus under Walter Gropius was “Art and Technology - a new unity” (Gropius, 1923). An architecture which strays far from this aspiration has lost its way, as does an architecture which avoids taking on board even seemingly radical new technologies in a comprehensive fashion. It is also curious that this tendency has emerged after a century where one of the basic tenets of Modernism, the single most influential of 20th-century architectural movements, was that “form follows function”. The position taken in this thesis is that not only are function and aesthetics not mutually exclusive, but that if perfect usability is achieved in design, including architectural interaction design, the resulting forms/outcomes should possess strong intrinsic aesthetic qualities. If architectural form follows function, then perhaps we must pose the question of how we define functionality. There is a

strong argument that the idea of “functionality” must now extend of necessity to include usability, with a consequent reframing of what “minimalism” entails. Minimalism cannot be equated with simplicity. Architectural minimalism which oversteps the mark can produce spaces which approach an architecture of sensory deprivation. Context, as always, is everything: a minimally-designed public space, carefully wrought of beautiful materials, may indeed be aesthetically pleasing. A small personal space conceived on equally minimal terms, without attention to a closer level of detail, and without the budget for fine materials, may read as hostile and uncomfortable. If we continue to entirely unnecessarily separate aesthetic concerns from those of usability, we will find our ability as designers to influence and control built outcomes dwindle. It might be timely to remind ourselves that minimalism, in relation to the European Modernist movement, was a purely intellectual construct, which consciously sought to develop an aesthetic appropriate to the “Machine Age”, and was defended against popular resistance. In many cases, it was conceived as a new architecture for the “common man”, though not one in which he had any voice. The same theme echoes in Le Corbusier’s “machines a habiter” (Jeanneret, 1923). The house conceived as a machine for living in is a viable proposition where it is a well-tempered machine, with comfort and usability as its fundamental concerns. The machine, however, should always be subservient to the user, not the other way about. American domestic architecture of the same period, between the two World Wars, concerns itself far more with user comfort, though the forms which arise are still unmistakably those of the Modernist movement.

The validity of an approach which sees aesthetic appeal and usability as flip sides of the same coin, is evidenced time and again in the market success of Apple products, where interfaces, operating systems and devices are seamlessly integrated into artefacts which of themselves possess strong aesthetic appeal. Considerations of design are fundamental at every level. Detractors are of the opinion that people buy the product because they “look good”, but this is to do a disservice to the quality of the interaction design and operating systems, which rely heavily on the

intuitive manner in which they can be accessed. The quality of the Apple user experience does not rely principally on either the physical design of the device, or the design of the operating system, but rather on the precise manner of how the user's many interactions with the device are articulated at the interface. Successful interaction design is the sum of all these parts, and more. Seeking for aesthetic quality and elegance in design solutions carries as much currency in interaction design as in architecture, and therefore, by implication, becomes a fundamental principle in the design of responsive architecture.

Calm Technology, Quiet Architecture?

Malcolm McCullough, writing in "Digital Ground", about the relationship between architecture and pervasive computing, makes a strong case for the continued role of architecture, even in a technologically-driven society, and emphasises above all the significance of context in situated interaction design (McCullough, 2005). He makes a case for what he terms a "quiet architecture" supported by "calm technology", as a successor to the egotism and obsession with external form that has characterised much of the architecture of the last generation. The idea of calm technology, fundamental to ubiquitous computing, is a seminal concept, described first by Mark Weiser and John Seely Brown (Weiser, M., Seely Brown, J., 1996). Calm technologies have the properties of being able to move to the centre of focus from the periphery and back, also allowing us to bring more details into the periphery, ready to be called on as needed. The result should be a sense of familiarity, or of being "at home" with the technology. Most interestingly, the first example of calm technology given by Weiser and Seely Brown in "The Coming Age of Calm Technology" is architectural: that of the internal office window, between cellular office and corridor. It permits awareness of external activity, on the periphery, and simultaneously allows the external observer on a corridor clues as to what is happening inside the office. Information flows in both directions. Open-plan offices, they argue, bring everything to the centre. Keeping things to the periphery allows us to focus on one thing at a time. Being able to easily move something from the periphery to the centre of attention is, in itself, calming. Attention is given to

something at the user's choosing. "High tech" in architecture does not therefore automatically need to be "high profile". In the case of localised interaction, it needs to be quite the opposite most of the time.

McCullough proposes that the principal role of pervasive computing in architecture should be to reinforce place-making and context, making a case for a "quiet architecture", where focus returns once more to the user. ICT is subsumed, as "calm technology", into the built fabric, and design for the sake of aesthetic novelty loses its power in the face of the inherent possibilities of an alternative embrace of technological potential. McCullough goes as far as to suggest that interventions made using pervasive computing technologies might be compensatory in the case of existing architectural design that has failed to address concerns of usability and human-centredness, so that "interactivity becomes a remedy for architecture, which as a discipline has ignored usability, performance and inhabitation in its quest for attention-seeking novelties in form." Themes of context, usability/inclusive design, minimalism, and calm technology run through the thesis proposal, where they are examined in the specific and intimate context of the personal life-space. There is a consensus that context is critical in interaction design, as a benchmark for "appropriateness". As McCullough eloquently expresses it, "appropriateness is almost always a matter of context. We understand our better contexts as places, and we understand better design for places as architecture". By extension, pervasive/ubiquitous embedded computing in architecture becomes understandable when framed by physical context. The precise nature of any designed interaction arises from consideration of three things: the user, the context, and the action taking place. The precise relationships between these three components inevitably impact on the experience of the user. In the case of embedded responsivity, context has exactly the same meaning as in its architectural sense, as the physical context of the building, the architecture. A "simple" or "minimal" interface, with usability as an implicit requirement, is also a function of the interplay between these three agents: Who? What? Where?, the "Holy Trinity" of interaction design in architecture.

User-centredness is a quintessential feature of successful interaction design. Architecturally-embedded responsivity offers an unprecedented opportunity to place the person, the user, at the centre of the interaction between person and environment. Simultaneously, it affords the architect to more fully inhabit the space between the user and her immediate environment. The role of systems architect and interaction designer would furthermore seem to offer a good “fit” with the traditional roles and responsibilities of the architect. The former facilitates control over the design of general aspects of the system, and the relationships between its various components and processes. Architects currently have an opportunity, therefore, to number among what John Maeda describes as “human technologists”, through the design of future environments which, through informed use of technologies, become more closely and directly connected to our bodies and senses. The development of a responsive and affective architecture based on a fully-integrated design approach to embedded computing has potential to influence, in the most profound manner, how we inhabit and interact with our built surroundings at every scale. In the words of Mark Weiser, “the most profound technologies are those that disappear”.

The role of architecture and built environment as the physical context, the container, for other technological artefacts must also be considered.

“Hyperfunctional” is a recent term coined by Sarah Kettley, a craftsperson and academic, to describe the types of multifunctional mobile web-enabled devices which are now a commonplace (Kettley, 2012). She queries whether they leave space, in either the intellectual or literal sense, for the crafted artefact. One solution to this particular dilemma, in architectural terms, is to subsume hyperfunctionality as far as possible into the built environment, returning the use of the space to the crafted and personal. Embedded architectural responsivity allows the technologies to recede into the periphery of the built fabric, either to operate quietly and largely invisibly, or to remain in the background until such time as they are required.

The conventionally-trained architect who wishes to step into the creative space of interaction design is likely find her current skill-set lacking: some knowledge of system design is required, and some knowledge of coding desirable. Many designers will recoil from this proposition. It likely that such attitudes have become ingrained in an educational system that insists on rigidly enforcing an often artificial distinction between the sciences and the arts, all the more so since the emergence of separate construction and design professions in the 1800s, where architect and engineer become separate entities for the first time. While we may not all need to be “Renaissance men” it would seem that at least some practitioners, on both sides of the science/art divide, must now assemble on common ground. The idea of collaborative design endeavour is hardly unknown in the architectural profession, where all but the smallest of commissions require inputs from an interdisciplinary design team, in which members of the ICT disciplines may soon come to take their places. In addition to some knowledge of ICT, education in behavioural science is a necessity for the interaction designer, as identified repeatedly in the writings of Don Norman (Norman, 2010). In the case of design for the built environment, this must extend to a basic grasp of environmental psychology, with more in-depth knowledge required for the design of interactions for specific user-groups. Malcolm McCullough’s contention that consideration of context should be at the core of the adoption of embedded technologies must be made paramount in order to ensure the realisation of an architecturally-coherent responsive space of any description. To state that responsive spaces require intelligence is a tautology: if they do not possess system intelligence, they will not merit the term “responsive” in the true sense, and such adaptation as may be possible without intelligence cannot hope to address the complexities of the individual user or the totality of possible interactions. The significance of physical context marks an essential distinction, in an envisaged world of embedded responsivity, from the parameters of universality and ubiquity around which many web technologies and interactions are designed. Architectural embedment is not the “everywhere” of cyberspace and the mobile web: it is place-specific, and more so, has potential to be, at the same time, user-specific and action-based. This represents a paradigm shift in terms of computing, where what is of relevance is the information specific to the person and their

actions in a given place at a given time, rather than the notion of instant access in any place to all of the information. It also represents, as such, an opportunity to move away from the age of digital information overload, when the requirement for conscious interaction with an ever-growing number of web and mobile interfaces has already begin to intrude significantly on available time, whether for work or for in-person social interaction. Viewed in this manner, it can only be welcomed by the architectural fraternity, as a contemporary extension of architectural theory about place-making and context, affording an opportunity for architects to engage, or re-engage, with the more intimate relationships between a space and the user. For many this may prove a welcome departure from an architecture of facadism, or one where building is reduced to a sculptural form in space, and no more, with little regard for considerations of usability. Users interact with buildings not only at the level of the spatial, but at the far more intimate level of detailed interaction. An acute awareness of such relationships informed teaching at the Bauhaus School. Gropius wrote extensively about the influence on the person of environmental factors, including colour. The study and manipulation of such “energies”, formed the basis of the Bauhaus education, which *“knew and taught that space relations, proportions, and colors control psychological functions”* (Cronan, 2011). Such approaches, which might be implemented by providing a grounding in environmental and behavioural psychology in the undergraduate curriculum, in addition to colour theory, have largely fallen out of favour in current architectural education. Gropius also comments that *“The key for a successful rebuilding of our environment -which is the architect's great task-will be our determination to let the human element be the dominant factor”*. (Gropius, 1962). A variation on this theme is found in Survival Through Design: *“Space is the stage on which design performs....design must serve physiological and social processes”*. (Neutra, 1954)

Architects sometimes choose not to engage with designing at this level of detail for a variety of reasons, including lack of competence, and lack of knowledge of the significance of the precise nature of these interactions in shaping the user’s experience of architecture. This feeds back into notions of what is meant by

multisensory design, and the reflexive stance that all design is, in the experience of the user, multisensory, whether or not this had been addressed in the design. Some of those more intimate interactions are beyond, or at best, on the edges of the remit of the architect as a designer, and cross over into the areas of furniture, product and textile design, in all of which architects have occasionally engaged, and where issues of aesthetics, ergonomics, and usability take on added significance. It is in the area of universal design, and design for users with specific deficits in ability which must be compensated for through environmental design, that the presence or absence of an intimate and thoughtful approach to design of the built environment becomes critically important. In such environments, the outcomes and effects of shortfalls in detail design on the user are particularly pointed and inescapable. In very many cases the same deficiencies have similar, but less pronounced effects on a general population of users, but the more vulnerable the user, and the greater the degree of compensation that the environment might be expected to provide, the more magnified any lack of compensation is. Interaction design, as it relates to design of embedded systems for built environments, must address face-on exactly the same challenges. Through a thoroughly informed and critical approach, what might hitherto have been viewed as serious constraints in architectural design, when mediated by the almost boundless potential of the technologies even currently available, become opportunities for creative expression. Hence involvement in the design of such interactions becomes the natural domain not only of the engineer or the technologist, but of the architect, working alone or in multidisciplinary collaboration. In architecture, multidisciplinary design teams are old news, as much so as creative and novel exploitation of engineering technologies. All that remains is that for a critical mass of design practitioners to equip themselves with even a basic skillset for interaction design, and the potential for new uses for embedded ICT systems begins to spring into being. Interaction design, as a discipline and a creative space, already exists. If it is equally populated by designers and technologists, with mutual respect for each other's skills, or by a new breed of designers who possess the necessary parts of both skillsets, that space has potential to be the scene of truly exciting developments.

AN AFFECTIVE RESPONSIVE ENVIRONMENT?

This leads to the central proposal of this thesis: that is, the concept of a responsive architectural environment where responsivity includes response to *affect*, or human emotion. In computing terms, the concept represents a synthesis of affective computing and responsive environments, which have to date been theorised and researched as separate fields. The thesis proposes, for the first time, an architecturally-embedded responsive system which is regulated by information relating to affect, as well as information about physical context. The aim is to optimise person-environment fit, not only in terms of physical congruence, which deals with issues of comfort and functionality, but also in terms of psychosocial congruence, or how the user feels. As has been commented previously, it has proven well-nigh impossible, in many instances, to separate out the two in the design of the physical environment. On that basis it would seem eminently sensible to approach integration of embedded sensor-based systems into architecture and built environment in the same manner: that is, as a two-pronged, and preferable seamless approach to cultivating person-environment fit, which actively seeks to address both functional psychosocial concerns.

The MyRoom model (Dalton, C., Harrison, J. D., 2010) (Dalton, C., Harrison, J. D., 2012) represents an expansion of Nicholas Negroponte's concept of "responsive architecture" (Negroponte, 1975), where an enhanced usability is achieved by maximising both functional and psychosocial congruence, and where that optimisation is mediated through adaptation of aesthetic and multisensory characteristics of a personal space actuated in response to real-time sensing. It occupies a theoretical space between that original concept and later, but purely aesthetic interpretations of responsive architecture. The model will further propose enhancing person-environment and user experience through aesthetic responsivity. Rather than responding to environmental factors, bio-sensing enables local environmental response to an individual user in that individual's personal space. The case examined in the following chapters is for a localised responsive environment, where the locale is the user's own room in a residential care or

supported setting for elderly people. It might equally be applied to any personal space: a bedroom, a cellular office, a hotel room, as much as to other single-room healthcare contexts. The rationale for enabling responsivity, including aesthetic variation, is that of therapeutic benefit, extending to salutogenesis. The case study is chosen with the awareness that the particular characteristics of the chosen user offer substantial challenges to successful design both of architectural environments, and for interaction design. A detailed examination of the needs of the user with dementia will not allow the designer to ignore the complexities and contradictions that arise in attempting to design for those changing needs. The hope is, that by exploring such challenges, specific solutions will emerge, which may also go some way towards addressing the needs of users in general. The model proposed in this thesis may serve not only to illustrate particular points as to how this person/environment relationship might be enhanced or mediated through use of ambient technologies, but further, as an illustration of how certain of the proposals for interaction are in fact generalizable, as they represent an enhancement of environmental interaction that can be extrapolated for use in many settings.

Specific issues arise also arise out of the particular context and nature of residential care, and the opportunities and limitations for environmental interaction arising out of the user's relationship with this specific context. Though it might seem at the outset that the functional necessities of any such care environment constitute an urgent imperative for designers, the review of environmental and behavioural psychology bears out that such a limited approach is counter-productive when it comes to promoting the overall well-being of an individual. The bulk of research in the area of technology for elderly people has been undertaken on precisely that premise, i.e. the notion of servicing functional need, and very often results in appliances and systems which have a technical rather than person-centred focus. Exceptions include research involving input from end-users and carers in identifying technologies and devices seen as desirable (Sixsmith, A. J., Gibson, G., Orpwood, R. D., Torrington, J., 2007). The advent of more and more gadgets and systems points

the way to overload in every sense from the cognitive to the technical, which is singularly inappropriate in the case of this particular user. It was a matter of both surprise and dismay to this researcher, for example, that many commercially-available home-based health monitoring systems for elderly people required not only a daily log-in, but time spent hooked up to a monitor. It is a source of puzzlement as to how such systems can be seen to be fit-for-purpose, or even of any benefit whatsoever in extending the ability of users, even in the early stages of dementia, to continue living on their own homes. How many users would be likely not only to forget to log in on occasion, but to actively resent the intrusion of having to do so on a regular basis? The fitness-for-purpose of many home alarm systems is also similarly questionable: of what benefit is a system that issues an alert only after an adverse event has taken place, in particular given the mortality rates in elderly people arising from falls in particular (Fuller, 2000). Reference will be made to the possible directions for alternative approaches to the above, as part of the same model of an intelligent and responsive room, or personal life space. There is no better case for a “calm technology in quiet architecture” approach than exists here.

While people have always modified buildings, the physical constraints of three-dimensional reality have implied that built environments have been heretofore largely static: the orientation of a space, the exact placement, shape and size of openings determine the precise nature of the relationship with external space, context, and the natural environment. Responsive architecture enables a paradigm shift from the personal life-space framed as a utilitarian “machine a habiter” to the possibility of a “living machine” whose focus is its occupant. The person who wishes to engage in interaction design at the scale of the built environment must occupy both the space of the designer of buildings, and the designer of systems. Interaction design, where architecture becomes the interface, occupies both worlds equally. The presence of the architect in this creative space draws her back relentlessly to examine the quintessential nature of the interface between the user and her environment, addressing a range of user experiences in a given context. By

extending conceptually the recent developments in responsive façade design, there seems to be space for a similarly nuanced approach to the design of adaptive and responsive internal spaces, where change is conceived in a proportional relationship to the size of the space, and is subtle and gradual, rather than sudden and attention-grabbing. The manifestation of technology in “quiet architecture” must be directed by thoughtful user- and context-specific interaction design. Never is that approach more appropriate than in the design of personal living-space for a vulnerable end user, where the approach taken must at all times serve to facilitate and enhance the user’s successful interaction with her immediate environment, including designing for the pleasure to be derived from such an interaction. The idea that certain parts of potential set of person/environment interactions should incorporate affective computing allows for the fascinating possibility for the personal space to become almost a living, breathing extension of the person that “owns” it.

The following chapters will proceed with an exploration of how such an environment might be imagined. It will refer inevitably to the design of a specific context, for a specific user, setting out a framework for contextualised architectural interaction in a specific locale, where the design is always conceived of as a synthesis of the built environment and the system which renders it responsive. The MyRoom model proposes a holistic responsive system which addresses concerns of both functional and psychosocial fit. In pursuit of the latter, it proposes to actively monitor psychological affect in real-time, using data from bio-signals in order to infer affect, which then becomes a factor in managing actuation of devices and applications. At the same time, the feedback loop between person and environment is closed when the changes initiated in the environmental context, i.e. the user’s own room, begin to act so as to alter affect in that individual.

The next section will first examine the “WHO”: that is, the characteristics of the user at the centre of the model, an elderly person in supported accommodation or,

alternatively, a residential care setting. This is followed by consideration of the “WHERE”: the physical context of care settings for elderly people, and how they have evolved. The subsequent chapters imagine in some detail the “WHAT”, in the form of principles for design interventions which support interaction between the person and context, and how they might proceed when augmented by embedded systems. The view is always that the technology must become virtually indistinguishable from the architecture, unless there is an identified advantage to its being made explicit, whether it emerges from the periphery in response to user need, or is present on a more permanent basis. The detail of how this is to be achieved will invariably be complex, involving as it must, complex programming and multiple interactions. The end-result, from a user perspective, should always aspire to simplicity and ease of use. While artists and architects are tentatively exploring the common space in artworks and installations, there is unlimited potential for exploration of “deep beauty”, where proffered design solutions not only delight the senses, but do so with the deeper intention of simultaneously addressing functional and psychosocial issues. Responsive architecture, of all possibilities, presents an opportunity to combine the two worlds of design and computing seamlessly. If architecture is a built expression of the zeitgeist, then responsive architecture, which has its roots in the twentieth century, must come of age in the twenty-first.

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Chapter 3

Architecture as interaction design I: the ageing person

- Changes associated with ageing
- Dementia
- Alzheimer's Disease
- Stress and dementia
- Designing for congruence for the older person with dementia

Introduction

Older people form a significant and growing demographic group. As we age, our physical and cognitive characteristics change. These changes inevitably alter the manner in which we interact with objects and environments, and can diminish our ability to function independently, depending on how environments and products are designed and made. The concept of inclusive design extends to designing so as to extend usability to people of all ages. Roger Coleman describes it as *“not a new genre of design, nor a separate specialism, but an approach to design in general and an element of business strategy that seeks to ensure that mainstream products, services, and environments are accessible to the largest number of people”*.

(Coleman, 2006)

For many elderly people, the loss of function and independence associated with dementia-related cognitive impairment is very often the marker for a move to residential care, and many older people in care have some form of dementia. In the US, in 2008, 45-67% of elderly people in assisted living and 68% of elderly people in nursing homes have some form of cognitive impairment, 47% with a diagnosis of dementia (Alzheimer's Association, 2013). By mid-century, someone in the US will develop AD every 33 seconds. Related impairments progressively affect an individual's ability to interpret and interact successfully with the environment, in addition to loss of physical function, including mobility, visual acuity, or hearing,

resulting from the ageing process. The capacity of environment to influence functioning of elderly people with dementia is well-researched (Day, K., Carreon, D., Stump, C., 2000). Much of that research has been translated into design guidelines, so that it is beginning to inform architecture and design disciplines, where the notion of psychosocially-supportive environments and person-centred design is gaining a tentative foothold. At the same time, it must be acknowledged that to date, in many societies the world over, people with dementia have been placed in institutional environments, which are very far from the norm in terms of living accommodation generally. As much as research draws attention to individual factors which have positive or negative effects on the user, so much does it become apparent that an integrated approach to environmental design is required.

This chapter returns to first principles for design for an elderly user, by summarising the cognitive and physical changes associated with normal old age, with age-related illness, and finally, those associated with the onset and progression of dementia. Taken together with the demographic changes described in the following chapter, these factors indicate an urgent need for provision of architectural environments which enable older people by a conscious aim to compensate, through design, for loss of ability associated with aging. More specifically, future-proofing buildings through inclusive design needs to take account of the predicted increase in the occurrence of dementia. Dementia is a progressive chronic disease which impairs cognitive functioning, including memory and reasoning, linguistic ability, mood, depth perception, and motor control. It leads to symptoms such as repetitiveness, wandering, combativeness, confusion, and secondary “Disturbed Behaviors” (BDs). Perception of sequence of events may be distorted, leading to disorientation and confusion. A person with dementia may feel shame or anger, being aware of their inadequacies; many may worry about the future, may feel confused and vulnerable and, perhaps most significantly, will have problems communicating needs or feelings. Ultimately there may be fragmentation of one’s very self. While dementia is not regarded as part of normal ageing, if the prediction of rates of occurrence of more than 50% in over-85s is correct, it will soon become the norm for the “older

old". (Alzheimer's Association, 2013) We clearly cannot continue to ignore design for dementia as an issue which must be addressed in design of the built environment; furthermore, it is recognized that physical environment can be therapeutic (Day, K., Carreon, D., Stump, C., 2000).

Design of person-centred environments which intend to cater successfully for elderly must aspire to respond creatively to the changing functional and cognitive characteristics of the end-user, never losing sight of that person's individuality. The need for different interventions depending on the stage of the disease is also recognised (Day, K., Carreon, D., Stump, C., 2000) (EIDD, 2004; Teresi, J. A. et al, 2000). To that end, given the predicted prevalence of dementia in the "very old" old, it is also essential that the designer understands the range and degree of impairment associated with the various stages of dementia as a progressive chronic disorder, and of Alzheimer's Disease as its commonest form.

CHANGES ASSOCIATED WITH AGEING

Our bodies change gradually, and in many ways as we age. Changes which affect our external experience, for example skin ageing, or loss of mobility and flexibility, are readily apparent to others. Other changes, such as to sight, hearing and metabolism, are less obvious externally. Some changes arise simply as a matter of getting older; others as a consequence of what might be termed "lifestyle diseases", which occur to a greater extent as we age. These include heart disease, Type 2 Diabetes, asthma, vascular disease, and Alzheimer's Disease, which can be associated with occurrence of other degenerative diseases. As well as impairment to physical ability, ageing is also associated with sensory impairment, again, through both normal ageing and age-related illness.

Many elderly people have more than one chronic condition or disease: these are referred to as "co-morbidities". Chronic illness can also adversely affect environmental fit. A number of chronic conditions, such as cardiovascular or pulmonary disease, or arthritis, can affect mobility, for different reasons, though

often with similar results: stairs become difficult to negotiate, long distances are tiring or painful. When movement is restricted or painful, steps can also be hazardous, as there is greater likelihood of falls. Dementia can have specific effects on mobility, including difficulties with balance, muscle rigidity, and shuffling gait, the latter turning even very slight level changes into a trip hazard. In its latter stages, movement becomes very restricted, as muscles atrophy. All of these changes impact how we function, and thus on how we interact with our environment.

CHANGES IN PERCEPTION ASSOCIATED WITH AGEING AND DEMENTIA

Sight

Most people require reading glasses from their 40s on, as they lose the ability to focus over a wide range of distances (presbyopia). This occurs because the lens stiffens with age, making it more difficult for the eye muscles to alter the shape of the lens in order to focus. Approximately 65% of people who are classified as having visual impairment are aged 65 and over (WHO, 2013). Age-related changes which affect vision include development of cataracts, where the lens yellows, and gradually becomes opaque. Age-related cataracts are the principal cause of blindness globally, accounting for 51% of all blindness. (WHO). There is general reduction in vision, with a sensitivity to glare in some cases. Cataracts can be treated by surgical replacement of the lens. Age-related macular degeneration (AMD) results in loss of the centre of the field of vision, and is another major cause of visual impairment and blindness in adults over the age of 50. In functional terms, as they relate to building design, impairment from AMD includes trouble discerning colour, slow recovery after exposure to bright light, and loss of contrast sensitivity. Other common causes of loss of vision in older people include glaucoma, and diabetic retinopathy, which arises as a complication of diabetes, itself more prevalent in older people. Dementia also causes specific changes in visual perception: damage to specific brain areas causes the person to lose the ability to

identify objects or recognise people, because they are no longer able to process visual information received by the brain. Other specific deficits in visual perception occur in Lewy Body Dementia, and in Parkinson's Disease, where visual dysfunction is regarded as profound (Uc, E. Y., et al, 2005). Visuoperceptual impairment contributes further to disability through its effect on cognition and movement. Visuoperceptual impairments associated with Parkinson disease dementia (PDD) are similar to those associated with dementia with Lewy bodies (DLB), but different from Alzheimer disease (Mossiman, U. P. et al, 2004).

Hearing

Gradual loss of hearing with age (presbycusis) is common. The ability to perceive higher pitches starts to decrease after about the age of 29, and continues to decrease as we age. Progressive death of cochlear hairs in the inner ear as we age causes a gradual loss of hearing sensitivity. Dementia can also affect auditory processing, just as it can affect other sensory processing. Cognitive impairment can lead to difficulty distinguishing meaningful from meaningless sounds, so that people with dementia may be easily confused or even upset by commonplace noises, and background noise levels. (van Hoof, J., et al, 2008).

Thermal perception (van Hoof, J., et al, 2008)

As we age, our tolerance of, and ability to recover from sudden changes in temperature diminishes. Sensitivity to changes in environmental condition is increased in people with dementia. Cognitive impairment from dementia may result in inability to correctly perceive temperature, or to fail to recognise it as the source of physical discomfort. Impaired thermal perception may be implicated in behaviours such as removal of clothing, or dressing inappropriately, e.g. for the wrong season, or by wearing outdoor clothes indoors. Loss of cognitive ability adversely affects ability to use thermostats and other environmental controls.

DEMENTIA

Dementia is not an inevitable consequence of age. Without it, cognitive performance can remain stable into old age. The WHO defines dementia as follows:

“Dementia is a global impairment of higher cortical functions, including memory, the capacity to solve the problems of day-to-day living, the performance of learning perceptuo-motor skills, the correct use of social skills and control of emotional reactions, in the absence of gross ‘clouding of consciousness’”. (WHO, 1992)

Dementia has different underlying causes, which are not fully understood, though there are genetic factors, which do not generally operate alone, but in tandem with other factors which predispose an individual towards developing the disease.

Variants affect different parts of the neural network. Alzheimer Disease (AD) is the most common cause of dementia, and accounts for about one-third of dementia in elderly people. Vascular dementia, e.g. dementia resulting from stroke, accounts for a further third, and the remainder is made up mostly of dementia which is a mixture of vascular and AD (Fratiglioni, L., 2000). AD is usually diagnosed by exclusion of treatable illnesses with similar symptoms.

In AD, “plaques” occur when protein deposits (“tau” proteins) build up on the outside of nerve cells in the brain, while protein deposits inside nerve cells lead to “neurofibrillary tangles”. Plaques and neurofibrillary tangles are characteristic of AD. Both also occur in some other forms of dementia, and to some extent in the brains of normal elderly people, with no diagnosis of dementia. Plaques and neurofibrillary tangles interfere with transmission of nerve impulses in the brain and from the brain to the body. Neural damage is progressive over the course of the disease, impacting comprehensively on cognition and functioning. Tau proteins appear to form along neural pathways, “jumping” across synapses to the next neuron. Protein formation starts in the entorhinal cortex, which plays a key role in memory, and serves as the main interface between the hippocampus and neocortex. Damage gradually spreads to affect other brain regions. Progression of symptoms reflects the area of the brain involved: for example, the hippocampus has a critical role in converting short-term memory to long-term, and also in spatial

navigation. Damage to the hippocampus largely manifests itself in impaired short-term memory. When the cerebral cortex (the outer layer of the neocortex) becomes involved, judgement is affected, and emotional outbursts may occur. There is overall shrinkage of brain tissue. The effect on memory has global repercussions, including on ability to perform sequential tasks, so that much of what has been learned over the course of a person's life is gradually lost, starting with loss of ability to perform more complex tasks and ending with loss even of basic reflexes, as well as loss of the sense of self, which is especially tragic for family and friends, but also very upsetting and frightening for the person with dementia.

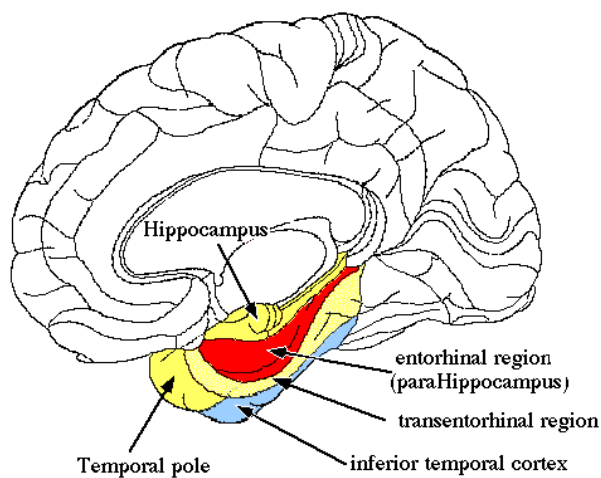


Fig. 3.1 Dementia initially affects the entorhinal cortex

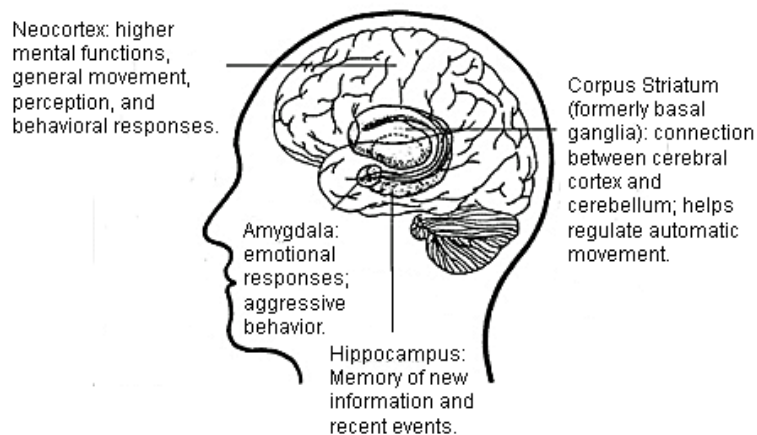


Fig. 3.2 Functions associated with different areas of the brain

Forms of dementia

While Alzheimer Disease (AD) is the commonest form of dementia, it is a common misconception that all dementia in elderly people is the result of AD. There are, however, a number of other forms, listed here. Alzheimer's disease is described, as the commonest from, is described in some detail.

Dementia with Lewy Bodies (LBD)

Dementia with Lewy Bodies (DLB) named after smooth round protein lumps, called Lewy bodies, which form in affected brain cells. DLB forms an important sub-category of dementia, as it is estimated that it may affect up to 20% of all dementia patents. It is characterised by profound visuoperceptual impairments (Mossiman, U. P. et al, 2004), and Parkinsonism (tremors, declining motor function), the latter more often presenting after dementia is diagnosed. The associated visual dysfunction also contributes to disability through influences on cognition and locomotion. Visual dysfunction includes vivid visual hallucinations, e.g. "seeing" faces, or other forms in carpets, shadows, etc. (Pareidolias). Minimising visual confusion is therefore of primary concern to the designer. Olfactory, auditory and tactile hallucinations may occur, but are less common. Memory, cognition and associated deficits fluctuate frequently in the person with LBD, over the course of a day/days/weeks. Progression tends to be faster than in AD. Lewy Body dementia may be regarded as a variant of AD.

Dementia arising from other disorders/ conditions

Dementia can also result from conditions such as Parkinson's Disease, and Down Syndrome. In the latter, onset is early. Parkinson's Disease Dementia (PDD) is also associated with visuoperceptual dysfunction. Vascular dementia, arising from lack of blood-supply to the brain, often results from stroke, with sudden onset. A small percentage of dementia arise from alcohol abuse.

ALZHEIMER'S DISEASE

Alzheimer's Disease is a chronic progressive disorder. This definition is of critical importance to the designer, for it effectively implies that design for dementia must cater for an end-user whose characteristics, including in terms of cognition and ability, vary over time, ultimately declining severely. After a certain point the person needs palliative care. To design one environment that caters for all these needs is be a difficult task; built environment alone cannot stretch to meet the needs of a person from the mid-stage of AD on, without substantial input from carers. An environment can, however, be designed to compensate for declining ability in order to extend congruence over time, to maximise functional fit and support psychosocial fit. The thesis proposes that technology, in the form of wireless sensor networks, has the potential to make a valuable contribution to enabling continued congruence on the part of the elderly user with dementia, through environmental augmentation. How far that contribution can extend depends on many factors, including the usability of currently available technologies, and how research is used to guide development of technologies, devices and applications.

Dementia as Disability

Perhaps the most productive way for the designer to consider dementia is by viewing it as a disability. Concepts of design for disability, and of "universal design" or "design for all" have gradually become a commonplace over the last thirty years or so. In the case of design for dementia, the familiar maxim that "good design enables, bad design disables" (EIDD, 2004) also comes into play. What is perceived as "good design" must be carefully reconsidered against the background of the symptoms of dementia, as many of those symptoms relate to interaction between the person and the built environment. As in the context of healthcare design generally, "good design" should also reflect the capacity of the physical environment to have a therapeutic effect on the user in terms of wellbeing in general, including psychosocial aspects. It is useful to allow the designer a less prescriptive approach to design of care environments than is evident in many

existing guidelines, many of which consist largely of restrictions on design, rather than a global view of what a supportive environment might consist of. It is of critical importance for the designer, as much as the client/service-provider to fully appreciate the degree to which the person with dementia has a lower and ever-decreasing capacity to deal with environmental stress, and the many resulting implications for the design of a successful environment in which that person can function optimally, with the best quality-of-life possible. Different individuals also display varying levels of functioning in comparison with actual neural damage at any given stage of the disease. Careful thought must therefore be given to how the physical environment may be a factor in this variation, and as to whether design can contribute to delaying deterioration in the person (Cluff, 1990). The character of the built environment may also impact significantly on the culture and delivery of care, and so also indirectly, on the end-user. This is discussed in more detail in the following chapter.

There is a very intimate relationship between the detail of design and ease of use, well-recognised in the area of universal or accessible design, and similarly between environmental design, and the degree of stress (or amelioration of) that an environment provides for the person. Stress is stress, whatever its source, and produces a specific physiological reaction in the person, which can lead to longer-term psychological and physical effects. This is a keystone of this thesis, both in terms of developing a broad design brief, and in relation to specific proposals for a responsive care environment. It can be extremely difficult, given the nature and effects of severe cognitive decline, for the designer to “stand in the shoes of” or identify with an end-user with dementia. However, an empathetic approach often makes for the best and most appropriate care design. Therefore it is useful to attempt to summarise the description of the disease and its progress to a set of characteristics to which the designer might respond creatively, creating an open-ended design brief for the design of dementia care environments. It is not helpful to issue design “edicts”, and quite underestimates the capabilities of a good designer, though this has become commonplace.

Charting the progression of dementia for an individual allows an evaluation of the point in the decline of that person where specific supportive intervention is required, and better identification of the point at which disability resulting from dementia is likely to result in a move into supported accommodation, or residential care. The quality of the home environment and the level and types of supports available from carers, which compensate to a degree for impairment in functioning, will result in different individuals requiring supported or residential care at different junctures in the progression of dementia.

Stages of Alzheimer's Disease

The following briefly describes the stages of Alzheimer's disease, the most common form of dementia, and summarises the progressive cognitive and functional impairment which characterise each of these stages (Reisberg). From a human perspective, it is a sad litany. For the designer, it is critical to understand that, as dementia is a progressive disease, the functional and cognitive characteristics of the person change over time, always deteriorating, and that the person's "stress threshold" is progressively lowered (Hall, G. R., Buckwalter, K. C., 1987). This can cause particular difficulties in designing an environment which will successfully optimise congruence for the remainder of a person's life after onset. In some ways, designing for a person with Alzheimer's disease, or any form of progressive dementia, is like designing for a range of users with vastly differing abilities, to which is added the complexity of designing for mostly irreversible decline, while striving at the same time to keep the individual, and not only the symptoms, in sight.

Who is this person? How does (s)he relate in terms of ability and functioning to "normal" person, or fit into the spectrum of ability? How can environments for people with dementia be designed to maximise functioning, compensate for ongoing cognitive and physical decline, and act therapeutically?

Stage 1: Normal

People who have no symptoms of cognitive or functional decline are described as normal, or mentally healthy, regardless of age. They do not exhibit any of behavioural and mood changes associated with dementia.

Stage 2: Normal aged forgetfulness (very mild cognitive decline)

According to US research, more than half of the population of persons over the age of 65 themselves believe that they have symptoms of decline in cognition or function. A characteristic example is a person's belief that he/she can no longer recall names as well as 5 or 10 years previously, or a belief that he/she is unable to remember where they have left things. Difficulty finding the correct word is also a common subjective belief, as is difficulty in concentrating. These symptoms are subjective, and others, even those close to the person, do not notice them as being different to what is termed "normal aged forgetfulness". There is some evidence that people who subjectively feel that they have experienced cognitive or function decline, where they do subsequently develop AD, go on to decline at greater rates than similar healthy older people who do not have these subjective complaints. (Braekhus, A. et al, 1998)

Stage 3: Mild cognitive impairment

The control of the person over their total environment, and the ability to interact successfully with it, begins to diminish. The person is still able to manage day-to-day living. Changes at this stage are still subtle but may be noted by those close to the person. Common problems include having difficulty remembering the correct word/name, trouble remembering new names, forgetting material that has just been read, losing or misplacing objects, and trouble with planning or organising. A person with Stage 3 dementia may repeat questions, or have difficulty in learning new skills, including new job skills. The ability to perform executive functions – to plan and organise- may also be affected. Many people with these symptoms also begin to experience anxiety. Outcomes vary: some people with these symptoms do not decline further, even over many years. A majority will continue to decline, showing obvious symptoms of dementia in a timeframe of two to four years. Most

people are halfway or more through this stage before they will seek medical advice, even where their symptoms have become noticeable. The full duration of this stage is therefore probably closer to 7 years. The person is still able to cope with Activities of Daily Living (ADLs), but may not be able to cope with their job, and may have to retire or stop work to reduce stress and anxiety.

Stage 4: Mild Alzheimer's disease

AD can be accurately diagnosed at this stage, as symptoms become more evident. The most common functional deficit is an increasing inability to manage activities of daily life, (ADLs) which involve complex tasks, for example, shopping for food, preparing a meal for guests, managing finances. The person may be unclear as to the date, or of how to pay the correct amount for a purchase. A familiar example is the inability to order from a menu. The reaction is often for the person to simply ask someone else to order. The person often seems less responsive emotionally, and may appear withdrawn. This is referred to as "flattening of affect". (S)he may also become moody, with either moodiness or flattened affect more likely to occur when mentally challenged, or in a challenging social situation. This may relate to the person's denial of their own condition, even to themselves, on the basis that if the person withdraws from activities or communication, they can avoid drawing attention to their cognitive deficits. The significance of this is revisited at a later juncture in the section on environmental interventions for people with dementia. In the same way that an accessible physical environment should be designed so as not to trip people up literally, an appropriate living environment for a person with mild AD must aim to avoid doing the same thing metaphorically. At Stage 4, the person may forget recent events, and also fail to remember parts of their own personal history, beginning what is often described as "loss of the person". This stage lasts about two years.

Stage 5: Moderate Alzheimer's disease

As AD progresses, deficiencies in memory and thinking become noticeable. It is at this juncture that the person may begin to need help with day-to-day activities. This is therefore a significant stage, at which the home environment becomes

critical in relation the degree to which it supports the person in their ability to remain living independently at home. At this point, the degree of environmental “fit” or congruence generally decreases to a point where this becomes impracticable, without significant support from carers and community. In the absence of a modified environment or available and continuous support, the person may soon need to make the move to a supported environment. Irish policy relies very heavily on assumptions about the availability of informal care from family and community. Supported living schemes are a rarity in Ireland, the usual remaining option being traditional nursing-home care, delivered on largely institutional lines.

Common memory problems for a person with Stage 5 AD include difficulty remembering where they are, what day it is, or what their ‘phone number or address is. The person may be able to remember on some occasions, but not others. This creates obvious problems with life outside the four walls of the house, which may be more or less severe depending on the nature of the context; e.g. in a small village or town, there may be enough people familiar with the person to literally send them home safely, and enough contact outside the home for people to notice failing abilities and allow for them to alert carers. This brings to mind my late maternal grandmother, who suffered from vascular dementia in her early 90s. She was quite happy to come and visit us, and was able to walk about the village, while my mother was safe in the knowledge that, should she become disorientated, pretty well everyone know who she was, and where to direct her. Living in a rural environment, especially living alone, or in a less close-knit community, will present greater challenges in terms of personal safety.

From this point on the person will begin to require assistance in choosing appropriate seasonal clothing, or may forget to change clothes without a reminder. More basic activities such as toileting or eating unaided are not yet affected. Even less challenging arithmetic presents problems, which will increase issues with

shopping, paying bills, etc. without assistance. People at Stage 5 of AD, who do not have adequate support, often become angry or suspicious, arising out of their confusion, including in relation to dealing with ADLs. The person now loses touch with major contemporary events, or may be able to remember such information only sporadically. Some longer-term memories may be lost, for example, former addresses, or schools attended. An educated person may have difficulty counting backwards from 20 in twos. This single fact serves as a particularly poignant reminder of how devastating the consequences of AD are to the person. Stage 5 lasts an average of approximately 1.5 years.

Stage 6: Mid-stage Alzheimer's disease: severe cognitive decline

Despite the appellation, which can be misleading if one is not familiar with the implications of what "mid-stage" AD entails, it is very clear after even cursory consideration, that the person will, by now, require constant care and supervision in order to live with any degree of security, or quality of life. From this stage on, many people will have been moved to a supported environment, if they do not have round-the-clock care available at home. As memory continues to disimprove, the person with Stage 6 AD will lose awareness of recent experiences, and of their surroundings. In other words, the person may not be able to recall or identify where they are. This does not imply that those surroundings should be designed with anything other than extreme care and consideration. The person will usually forget names of even close family and friends, though will still recognise them as familiar. Help or prompts are needed in order to dress correctly. Sleep patterns show disruption, with sleeplessness at night becoming common, as well as sleeping during the day. Changes in sleep patterns are also associated with normal aging. The person will require assistance with toileting, and will have increasingly frequent problems with continence.

The person will remember his/her own name, but little personal history, which is essentially what makes a person who they are. Recent research maintains that

much procedural memory (i.e. how to do things) remains robust in people with dementia, even when declarative memory (memory of facts and events) is lost, as the neural pathways necessary to access it are damaged. It is possible to adapt tasks and activities to draw on procedural memory rather than declarative memory, in order to support functioning. The issue of retained memory also points up a critical issue in the development of care models, and by extension, of architectural models, or models of dementia care: however helpless the person may become, this is an adult human being replete with a lifetime of memories and personal associations. The temptation to infantilise must be resisted, other than in the name of sheer practical necessity, of which there are many.

This is when many people show major personality and behavioural changes, which can be extremely difficult for family to cope with. It is this aspect of “loss of the person” that the person’s family often feel most keenly, more so than the person’s loss of ability to care for herself. Changes include suspiciousness and delusional behaviour, and also compulsive or repetitive behaviour, (hand-wringing or tissue-shredding, for example). At this stage, the person is unable any longer to carry out the basic activities of daily life. There are five successive sub-stages identified in Stage 6, in terms of loss of function. This is still termed as “moderately severe Alzheimer’s disease”, though this might appear to understate the extent of the loss of independent functioning. The stages are briefly set out here as a prelude to discussion of possibilities for design intervention to support caring and reduce stress.

Stage 6a:

The person begins to need help in dressing correctly without supervision, e.g. with garments in the right order.

Stage 6b:

The person becomes unable bathe without assistance. The earliest characteristic problem is difficulty adjusting the temperature of the bath water, but bathing can still take place independently for a time, if a carer adjusts the water temperature.

As this stage progresses, other problems in bathing and dressing arise, including loss of ability to brush teeth independently.

Stages 6c, 6d, 6e

After Alzheimer's patients lose the ability to dress and bathe without assistance, they lose the ability to independently maintain cleanliness in toileting.

6c: Person cannot manage toileting without help; may forget to put tissue within reach, or flush.

6d: Person develops urinary incontinence.

6e: Person develops faecal incontinence.

Incontinence may initially be treated, or effectively prevented, by introducing a supervised toileting regime. Room and building layout can assist, by making toilets clearly visible and directly accessible (e.g. from the person's bed/sitting-area, from a shared living-room). Eventually, incontinence is not manageable even by these interventions.

The cognitive loss associated with Stage 6 AD deficits is generally so severe that the person displays little or no understanding or awareness of their current life circumstances, current address or weather conditions. The person may not remember basic facts such as parents' names, though usually remember their own name, and often confuses the identities of others, including close family, for example, mistaking their spouse for a deceased parent, even in context. This may be connected to longer retention of longer-term memory. At the end of this stage, speech ability breaks down.

Emotional changes generally become most overt and disturbing in this sixth stage of AD. Although these emotional changes may, in part, have a neurochemical basis, they are also clearly related to the patient's psychological reaction to their circumstances. For example, because of their cognitive deficits, patients can no longer channel their energies into productive activities. Consequently, unless appropriate direction is provided, patients begin to fidget, to pace, to move objects around and place items where they may not belong, or to manifest other forms of

purposeless or inappropriate activities. Because of the patient's fear, frustration and shame regarding their circumstances, as well as other factors, patients frequently develop verbal outbursts, and threatening, or even violent, behaviour may occur. Because patients can no longer survive independently, they commonly develop a fear of being left alone. Treatment of these and other behavioural and psychological symptoms which occur at this stage, and at other stages of AD, include pharmacological interventions, and provision of appropriate activities. An incongruent physical care setting that contributes to frustration may contribute to behavioural problems; this notion is developed further later in this section. Deficits in sensory perception are particularly pertinent in design of the built environment, which suggests that design of purpose-built environments for people with dementia should extend to inclusion of compensatory measures. An appropriately-designed environment which maximises both functional and psychosocial congruence also has therapeutic potential.

Stage 6 AD lasts on average for approximately 2.3 years. As it comes to an end, the patient is typically doubly incontinent, needs assistance with dressing and bathing, and begins to show obvious breakdown in speaking articulately. Stuttering and neologisms may feature, or a decrease in speech. While this presents a heart-breaking prospect for family and carers, the designer but must always first consider issues, no matter how difficult that might be, from the perspective of the person inside the illness.

Stage 7: Severe or late-stage Alzheimer's disease: very severe cognitive decline

In the final stage of AD, the person loses the ability to respond to her environment, to carry on a conversation and, eventually, to control movement. (S)he may still say words or phrases. At this stage, AD patients require continuous assistance with basic activities of daily life, in order to for survive. Six functional sub-stages may be identified over the course of the seventh stage. Each sub-stage lasts an average of 1-1.5 years.

Stage 7a:

Speech becomes limited to approximately a half-dozen intelligible words or fewer, even when an interviewer makes numerous efforts to elicit a response. Average duration is 1 year.

Stage 7b:

By now, speech has become limited to, at most, a single intelligible word. Once speech is lost, the ability to walk without assistance is invariably lost (stage 7e), though walking ability is often becomes affected earlier on, from the end of Stage 6. A very good level of care in Stage 7a can help retain walking ability in stage 7b, sometimes over a period of years. Usually, however, the duration of Stage 7b is 1-1.5 years. Where people live beyond Stage 7b, they progress during Stage 7c to lose ability to sit up independently, marking the beginning of Stage 7d, At this point, arm rests for chairs are essential, or the person will fall over when seated.

Stages 7c-7f:

Stage 7d lasts approximately 1 year. People who live past it subsequently lose the ability to smile, at Stage 7e, and can only grimace. Stage 7e averages 1.5 years. In Stage 7f, the final sub-stage, the person loses the ability to hold up her head independently, finally becoming immobile, so much so that s(he) must be supported in order to sit up. The neck may become contracted and immobile. Patients can survive in this final 7f sub-stage indefinitely, though most die before reaching the ultimate stages. People can, with appropriate care and life support, live with Stage 7f for several years. During Stage 7 of AD, characteristic physical and neurological changes become increasingly apparent. One of these is physical rigidity of major joints, e.g. the elbow. In many patients, joint rigidity (even for passive motion) precedes the appearance of contractures, causing visible physical deformities, which are irreversible. Early in Stage 7 approximately 40% of people with AD patients manifest these deformities, with the result that they cannot move a major joint more than halfway. Later in Stage 7, nearly all AD patients will develop contractures in multiple extremities and joints. People with Stage 7 AD often die from pneumonia, related also the inability to sit upright, with pneumonia often caused by aspiration. Infected bedsores are another common cause of death. Stage 7 AD patients in appear to be more vulnerable to other common causes of death in

elderly people, including stroke, heart disease and cancer. Some Stage 7 patients, however, die from no identifiable condition other than AD.

The progressive loss of abilities often appears like a cruel and protracted reversal of the order in which abilities are acquired in infancy. In fact, the person begins to show “infantile” neurological reflexes, which are also present in infants, but disappear at the toddler stage. These include the grasp reflex, and sucking reflex. Because the person is a fully-grown adult, these reflexes are physically strong, and impact on care, both positively and negatively. Perhaps, though there is another lesson here to be learned for designers and care-providers: one would never consider leaving an infant without appropriate mental and physical stimulus.

DESIGNING FOR CONGRUENCE FOR THE OLDER PERSON WITH DEMENTIA

Development of a more comprehensive design brief, based on a closer examination of the person, can begin to explore the creative potential of designing environments for an increasingly significant and very vulnerable section of society, which may well include our future selves (Coleman, R., Pullinger, D.J., 1993). Over the course of the research, this question has recurred: “How would I like?” “What would I do?” if confined within the type of care environments in which elderly people, and people with dementia are currently expected to live as a matter of routine. The answer, too often, is “become upset”, “get depressed”, or even “turn my face to the wall”, to use a common expression. These instinctive reactions unfortunately resemble closely what were once seen as primary symptoms of dementia, but are now more often likely to be viewed as secondary symptoms, arising out of environmental deficiencies as much as anything else. “Gut reactions” turn out to be of significant import, as we shall see later in this chapter. The worst situation I have ever seen was a ward of approximately 10 metres by 6, housing 6 or 8 elderly people with dementia. The room was intersected by L-shaped circulation between two doors set in walls at right angles to one another. I can scarcely conceive of an environment less conducive to normal human functioning, even for

an unimpaired person. To imagine life on that ward with cognitive impairments, confusion, restriction on intimate personal space, the lack of anything indicating personalisation, of personal property or artefacts, was truly upsetting. How anything but a negative outcome could be expected for a person with dementia in such a setting is beyond my comprehension. This was a care setting constructed in this century, not the last century, nor even the one before. The fact that it was supposedly purpose-built was even more startling. It could not have been less fit-for-purpose, taking into full consideration the likely characteristics and needs of its intended users, of which the service-providers were supposedly fully-cognisant, deeming themselves expert. It demonstrated a still-prevalent inability to shake off an institutional view of the user, who was above all, to be contained, and corralled within the very small space of the unit. From a personal point of view, it was, I suppose, a Damascene moment. No person in a society which considers itself to be civilised should be required to live in such a fashion, much less a vulnerable and confused elderly person. Consideration of the effect of the change from home environments to a care environment does not seem to feature highly in available research literature. Perhaps decline is assumed as inevitable; equally, as a designer, given the emergence of relevant evidence, it is possible that considered design might restore some functioning by compensation for impairment, or at least slow the rate of decline.

Humans have always modified their surroundings, and local environmental modification is often essential to maintain congruence. However, it becomes increasingly difficult as dementia progresses, for a person to successfully interact with or modify personal surroundings in order to achieve congruence, or even basic comfort. The person comes to rely almost completely on a carer, both as an interpreter of needs, and of effective and appropriate action to modify the environment. Cognitive impairment due to dementia is often accompanied by further physical or sensory impairment from age-related disease, or simply from the process of aging. An unimpaired person might verbalise their dissatisfaction with a specific environment, e.g. "it's too dark", "the sun is in my eyes", "there's nowhere

for me to sit and talk”, “I’m bored”. They might then make changes, by switching on a light, closing a blind, getting a chair, initiating a conversation or reading a book. If the immediate environment is sufficiently uncomfortable, an unimpaired person may ask someone else to assist, move to another room or simply leave. Most or all of these courses of action may be unavailable to a person with dementia, or a critically ill patient, or even to a person with mobility problems. If needs are not met, the person may become stressed or upset. For a person with dementia, this may happen many times over the course of the day. Many disturbed behaviours associated with dementia are now seen as meaningful expressions of needs that must be addressed (Kolanowski, 1999); it is also immediately apparent how much the built environment can contribute, or not, to meeting the needs of the person. If a person become very physically confined through impairment, be it temporary, permanent, or chronic and deteriorating, the person’s own room must attempt to meet all requirements for both physical and psychosocial congruence. It often effectively becomes the entire “personal life space”, especially in the latter stages of dementia.

STRESS AND DEMENTIA

Stress, including stress arising from deficits in environmental fit, is recognised as a contributor to both psychological and physical illness, through its effect on the immune system, including over a longer time-frame (Graham, J., Christian, L., Kiecolt-Glaser, J., 2006). As more is discovered about how our bodies and brains function, the distinction between physical and psychological wellbeing becomes increasingly blurred. Wellbeing involves both body and mind. Anything which impacts on emotional or mental wellbeing may come to impact on physical wellbeing, though the influence of stress on our biochemistry. It should be noted that the short-term stress response in the brain is healthy and adaptive, but the effects of long-term, chronic stress tell a different story.

Causes of late-onset AD are not fully understood, and probably include a combination of genetic, environmental, and lifestyle factors. There is a known genetic cause for “early-onset” AD (Rogaeva, 2002), which usually begins to manifest after the age of 60, though less than 5% of AD is thought to result from transmission of dominant genes. For late-onset AD, while there are a number of genetic markers which indicate a predisposition towards the disease (Naj, A.C., et al, 2011), their presence alone does not imply that a person will go on inevitably to develop AD. This is where other factors, such as lifestyle and stress, may play a role in determining gene expression. Stress is implicated in dementia in a number of ways, both as a known precursor (Johansson, L., Guo, X., 2010), as a trigger for onset, and on an ongoing, day-to-day basis. Stress is known to affect expression of gene traits for cancers, as well as having a critical role in the development of autoimmune diseases. As we age, our body’s ability to adapt to stress diminishes. This may be the reason that the longer we live, the more likely we are more likely to develop dementia. A recurring theme elsewhere in gerontology is that chronic stress can accelerate the aging process (Umea University, 2011).

Stress is known to suppress the central immune response, and causes an inflammatory response, from which brain cells are not excepted. Chronic stress causes changes to brain chemistry, including changes to the tau proteins, which are part of the neuronal (nerve cell) structure. (Osborne, F. X., Almeida, et al, 2011) This mechanism has been demonstrated in lab rats. It has also been shown that “aged” rats are unable to switch off secretion of stress hormones at the end of a stressful event. The same chemical changes have been found in the neurons of people who have died with AD. These changes affect the neuron’s ability to transport biochemicals, and so compromise their ability to function in the transmission of neural impulses. Stress also affects the functioning of the glial cells, which are involved not only in the brain’s immune response, but also in most other aspects of brain function. The glial cells are normally responsible for clearing toxins from the brain, but cease to do so effectively in the continuing presence of stress hormones. The continued presence of the toxins triggers further neurochemical changes,

which are inflammatory, and may be implicated in the progression of neurodegenerative diseases, of which AD is one. (Juaregi-Huerta, F., et al, 2010). These events in themselves further reduce the capacity of the brain to deal with stress, creating a downward spiral of neural damage. The hormones released during stressful conditions are known to influence many brain processes, including brain development, cognition, memory, behaviour, growth of neurons, and what is known as neuroplasticity, that is, the brain's ability to form new neural connections, including to replace damaged connections. Stress (including stress arising from the condition) can interfere with the possibility of repair and growth of new neural pathways to replace damaged ones. It may be possible to promote neuroplasticity in dementia patients (Kolanowski, A. M., et al, 2010), so there is cause for cautious optimism. Learning can potentially counteract against a small amount of cognitive decline. Thus while stress is a causal factor in AD, the resulting impairment can itself become a source of further stress for the person, creating a vicious cycle, which continues to exacerbate the symptoms and progress of the disease. Stress also exacerbates other disorders that drive up risk for AD, such as depression, diabetes, and metabolic syndrome (Placeholder56).

There is some support for the idea that AD may be an autoimmune disease of the brain. It is acknowledged that stress has a role in autoimmune disease of all descriptions: they are generally regarded as multifactorial, but with a specific event or pathogen implicated in onset. When data on autoimmune diseases was retrospectively analysed, 80% of subjects had experienced acute emotional stress shortly before onset. (Stojanovich, 2008) Immune activation, which is the first step in the onset of autoimmunity, has been shown in patients with Alzheimer's disease (Singh, 1996). Impacts of stress can also accumulate progressively over a person's lifetime, reducing the reserve capacity for the brain to cope with stress. Research has also demonstrated an increased incidence of AD/dementia in women who have experienced severe stress in midlife. A correlation between bereavement, particularly of a spouse, and onset of dementia, has been established. (Charlton, 1995) Other stressful events known to impact on autoimmune disease include

moving home (Placeholder57). If this is the case, there is a distinct possibility that the move from lifetime home to care setting may in itself be a cause of significant deterioration in a person with AD, though there appears to be little research around the effects of such a move on the person it is most likely to affect.

The ongoing susceptibility of the person with dementia to environmental stress has significant implications for dementia care, extending to design of appropriate living-places, so as to carefully manage stress of environmental origin. On a day-to-day basis, the person's lowered stress threshold predisposes her towards the sort of "catastrophic events", which characteristically occur in late afternoon. Though referred to as "sundowning", the behaviours largely appear to be the result of stress overload from the many stresses accumulated over the course of an ordinary day. Some of them may be secondary, rather than primary symptoms, arising out of loss of function and environmental fit, due to cognitive impairment, and as such, may respond to environmental intervention. This is where environmental design takes on critical significance in terms of enabling the person with dementia to continue to live with quality-of-life and optimal functioning. That influence may extend as far as reducing need for medication, if disturbed behaviours of environmental origin can be reduced or eliminated. In the language of the designer, characteristics such as way-finding, space provision and disposition, clarity of spatial relationships, and detailed design all have potential to improve the daily life of a person with dementia. Design interventions are therefore possible on every scale with which the architect deals. A lowered threshold for environmental stress implies that the person with dementia may become easily stressed when interacting with an environment. Damage to memory can affect something as simple as remembering when, or even how, to turn on a light or manage other environmental controls. Such abilities are lost during the progression of AD. The ability to communicate need verbally is also compromised and ultimately lost completely. It should not be a matter of surprise then, that a person can become cumulatively more stressed as the day progresses. The smallest of tasks can generate major frustration. In neurochemical terms, a person with dementia also

takes longer to recover from stress. It seems that the person with AD may live in a near-permanent stressed state, only exacerbated by the fact that the neural damage and impairment caused by AD renders them ever more unlikely to be able to cope with their environment, with the result that environment progressively becomes a source of even greater stress.

As dementia progresses, the ordinary becomes the impossible; what was formerly easy becomes unachievable. It is difficult, as an observer, to fathom the impact of this on the person, on his/her self-esteem, and perception of self. Many people with dementia are not only aware of, but ashamed of their symptoms, which can become a cause of acute anxiety, and avoidance. The potential of good design as an enabler of optimal functioning and as a de-stressor begins to become clear, most especially where design is consciously inclusive, and does not overtly single out the individual for special treatment, but aims nonetheless to accommodate her needs. My personal credo with respect to accessible or inclusive design has always been that it should be invisible insofar as possible; the same should apply to designing successfully for an older person who has, whether or not they go on to develop dementia. Informed and thoughtful design has much to contribute, and marks the essential difference between an integrated design approach, and an environment which is the outcome of a “box-ticking” exercise: which obeys the “dos and don’ts” of accessible design or design for dementia, but which on the whole, is unsuccessful as a coherent piece of design.

The implications of loss of memory in dementia go far beyond simple lost recall of events: memory is essential in supporting cognitive abilities, through retrieval of learned tasks and skills. Impairment affects the ability to carry out tasks that have been learned, and which are subsequently re-accessed through memory; in the same way it compromises problem-solving, as previous solutions cannot be accessed. In the early stages, after it becomes apparent, it may interfere with the ability to continue in one’s job; later on a person will lose the ability to manage

complex tasks, such as planning a week's shopping for food; gradually simpler abilities are eroded. A person will be unable to handle money, or perhaps to make a choice from a menu. Social situations involving a number of people may become distressing. Often the person will avoid such situations as they become a source of stress and embarrassment. She may also avoid acknowledging the existence of the condition, though there is a kernel of truth to be found in this view, if one accepts the degree to which environment can disable the person. I am reminded of a casual encounter with a very elderly, and very deaf lady, who kept apologising for her mental confusion, much of which undoubtedly arose from her inability to hear what I was saying. A hearing-aid might have dealt with much of her perceived confusion.

It is very important for the designer, as much as the caregiver, to understand the progressive nature of the disease: while the root cause of cognitive impairment and loss of function due to neural damage and loss is the same, the consequences become more and more serious as more and more skills and abilities are lost. A person will lose a sense of temporality, and with it the realisation that is, for example, the right time to eat. Eventually the ability to prepare food without supervision is lost, and in the final stages, the ability to feed oneself. The "loss of the person" is often the most difficult aspect for family members to take on board. It does not refer only to the loss of personal memories, starting with short-term memory, and extending to loss of life memories, and eventually inability to name or even recognise close family and even the person's own reflection, which can then become a cause of fear. It also refers to the loss of accumulated abilities and skills, and loss of understanding of relationships, that make a person unique and individual.

PATHOLOGISING OF BEHAVIOURS THROUGH POOR DESIGN

The manner in which behaviours associated with dementia are regarded, and managed, often pathologises them needlessly (Dupuis, Sherry L., et al, 2012). This has been recognised only relatively recently, to the extent that some behaviours, which were formerly categorised as primary symptoms of dementia, are now

regarded as secondary, an outcome of how dementia affects the person's actions and interactions. Examples described in literature include a carer's perception of behaviours as being viewed in a negative light because they are "filtered" by considerations arising only from the person's status as a dementia patient, and further, by assumptions made about cognitive ability and often, patient safety. Pathologising of what might otherwise be considered as normal behaviours (e.g. forming intimate relationships) can massively restrict a person's quality of life. The very same lenses, most frequently those of "safety", are used again and again to justify continued use of institutional environments for elderly people to live in, to the extent that design briefs quite often inevitably result in an often recognisable style of care architecture which tends very much to enclose and restrict, and effectively controls behaviour, by restricting available choices. The question instead must be: What are the person's needs? What needs does the person's behaviour communicate? Those needs are inevitably both functional and psychosocial. Many of them may be met through thoughtful and genuinely user-centred design of the physical environment.

Perceptions of what are currently described as primary and secondary symptoms may continue to shift as ongoing research examines them more closely. Research should include detailed re-examination of the nature of interactions between the person and the built environment. "Wandering" is one obvious possibility for examination. The person with mid-stage dementia is described as tending to "wander" or become lost: this in many ways seems to be a reversal of how the same pattern of movement might be viewed in an unimpaired person. Wandering can only be described as such if it has no purpose, but the person with dementia may have had a purpose in mind but is unable to retain it long enough to act on it, and therefore the apparent intention is reduced to what is described as "wandering." One can only assume that being placed in an unfamiliar and impersonal environment, with poor way-finding, can exacerbate this. "Wandering" may become quite understandable in the light of the issues with memory: if one cannot find something or somewhere, the tendency is often to keep searching,

which may appear to be aimless wandering. Clearly environmental design can be of some assistance here, by employing clear way-finding, and producing comprehensible and “legible” buildings, using familiar and scale-appropriate architectural language. In some care settings, “wandering paths’ have been provided, both internally and externally. There are other design approaches available. As an architect, I would plead for authenticity and familiarity, as the more inclusive approach, rather than substitution with what is effectively a “stage-set”. That is, the broader architectural setting should employ familiar and recognisable features, designed to minimise the chances of becoming lost, but maximising freedom of movement. The same comment applies to buildings and settings in the public domain, for users in general. Very many contemporary Irish healthcare settings seem to place enormous reliance on a proliferation of signage, often to the degree where it becomes of itself confusing, whereas a more comprehensive designed solution would aim for the building to first “speak for itself”, through use of three-dimensional characteristics of form and space, with colour as a supplementary aid to way-finding.

Hotel California

The ability to move freely, to go out and about, to return home, to have choice about one’s behaviour in day-to-day matters, is normal, and taken for granted, for most of us. Being restricted to the same indoor space, or to a very small outdoor space, and being unable to leave those confines, is manifestly not normal. Restriction of movement of elderly people in care has progressed, thankfully, but only recently, from actual physical restraint to a bed or chair. While provision of “wandering paths” represents progress, it should be no surprise that many residents of care facilities become frustrated with their inability to exit a building or floor (in a multi-storey facility), and not unusually resort to all sorts of stratagems to evade their “captors”. Why would they not? If someone –and an apparent stranger, at that – restricted you to a constantly unfamiliar and inhospitable building, wouldn't you try to leave? It is also not “normal” to be restricted to the inside of one building, unless one is a prisoner. If a “normal” (Stage 1) person was subjected

to the same constraints on behaviour and on living, one might justifiably expect negative outcomes in terms of both wellbeing and behaviour. It is also recognised that wandering in dementia is a response to stress, possibly in the same way that physical restlessness is characteristic of otherwise “normal” people with PTSD. But despite all this, “wandering” has largely been seen as a problem with the person, rather than a problem with the physical setting, or the total environment of care.

A persistently institutional view of an individual allows what in many cases might be seen in other contexts as quite normal reactions (albeit from a confused individual) to be pathologised. As a designer in practice, I have experienced a stark difference in attitude, most surprisingly, between care of people with special needs, including profound mental disability, and that of elderly people. In the latter case, there was significant emphasis on “quality of life”, and in maximising that aspect of care, even in the face of seemingly insurmountable obstacles. In the former, there often seemed, and seems, to be a tacit assumption that there was nothing to be done, as there was “nothing there”, and that elderly people with dementia were to be more or less contained, for their own good. Unsurprisingly, the Care Quality Commission in the UK found recently that elderly people care were being subjected to “blanket restrictions”, such as locked doors on wards and day-rooms, in many NHS hospitals and residential care homes (Care Quality Commission, 2012).



Fig. 3.3 You can check out any time you like, but you can never leave

There is a relatively recent consensus that places for caring for people with dementia should aspire to being ‘homelike’. The caveat for both designer and carer is that this may well mean different things to different people; some of these factors may be quite intangible, and difficult to identify and realise physically in the designed environment. From the designer’s point of view, the concept of home requires close examination, if we aspire to create an identifiably familiar place for the person. It is commonly known that people in dementia care settings frequently want to go “home”, and are unwilling to accept that they are “at home”. However, viewed objectively, this may be as much a consequence of the deficiencies of the types of care environment in which we expect people with dementia to live, with dementia, (as that is what they continue to do, until they die) as it is of some cognitive deficit on the part of the person. The concept of “home” is much more than just a word. Words alone will not convince even an unimpaired person of the truth of the statement “this is home”. It can only add to confusion and distress to be told that a place is “home” when it not only very obviously not, and does not even possess the basic physical characteristics that might enable it in time, or ever, to become “home”. Perhaps it should not, therefore, be a matter of surprise when an elderly person expresses a wish to leave, or attempts to leave what is obviously an institution, with the architectural language of institutional architecture, in order to go “home”. Instead that behaviour is pathologised on the basis that (s)he is “confused”, and that “this is your home now” when everything about it bespeaks otherwise. It is hardly any more surprising that (s)he might wish to “wander” or go “out”. Going “out”, for recreation, shopping or work, and returning “home” is a normal part of home life. This alone would seem to indicate that care for people with dementia should be located within existing communities, but that also the living-place should not be isolated in an institutional setting, but permeable to interaction with the community in which it is situated, ideally that from which the residents originate. This has been the norm in New Zealand and Australia for many years, and is a far cry from the types of care model which are almost hermetically sealed for the “safety” of the user, and which sometimes aim to recreate an artificial facsimile of external environments within the unit. Some of the design diktats, which ostensibly arise from concerns about safety, appear to be generated

to a much greater extent from concerns about efficient staffing, than from consideration of the user as a person, so much do they encroach on the possibility for any normal quality-of-life. There must be a middle ground, where the user's needs as a person, albeit a vulnerable one, are addressed. There are existing successful architectural models which support both psychosocial and functional needs, some of which are reviewed in the following chapter.

As even a casual observer of how care buildings which I have designed have subsequently been used, it becomes clearly apparent that the culture of care, and how a building is used, even in physically similar architectural contexts, is most often driven by local management style. This appears to be very significant in terms of how the architectural space is used, and whether its inherent potential is optimised. The reverse also applies, that is, the physical place influences the possibilities for care, and is discussed further in the following chapter. It should be stressed that the very restrictive approach prevalent in Ireland, and to a large extent the UK, it appears to be a particular phenomenon in some countries, but not others, and that much less restrictive approaches to design of environments for elderly people and dementia care are evident elsewhere. The current situation also has its origins in a society that formerly, and until very recently, "warehoused" not only elderly people, but also those who with mental and physical illness, or simply those who were unable to support themselves. While social housing has long been a reality, and care of persons with mental health issues in community settings a more recent progression. It seems that in Irish society, the proper housing and care of the elderly is that last of those bastions to be breached.

Creating a familiar and home-like environment takes on particular significance where the person no longer resides in her lifetime home. The recent change in how "disturbed" behaviours are viewed provides an impetus for considered intervention, not only in the type of care-giving, but also in the design of care environments, so as to maximise the possibility of the user continuing to live as

normal a life as possible. This is to be achieved both by designing for ease-of-use, compensating for loss of ability, and equally, by addressing psychosocial issues, including by consciously setting out to minimise environmental stress. This will be played out in many cases in the detailed design of spaces and places, which will be explored further in subsequent chapters. In many cases, changes to the way objects or buildings are designed stand to benefit all users.

In the light of the above, we must pause and examine architectural models of care, which we have to date deemed suitable for the elderly person with dementia, and which, in Ireland are still overwhelmingly institutional in nature. The next chapter will examine how this situation might have come about, and the degree to which existing care environments fail catastrophically to meet the known needs of people with dementia, from both a functional and psychosocial perspective, before moving onto a review of new models of care. Design of living-places for elderly people, whether in their existing homes, in supported housing, or for end-of-life care, must inevitably address the issue of designing for the specific needs of persons with severe cognitive impairment, while current care models, such as described by Gadow (Gadow, 1988), aim to prevent the loss of the person to the disease. In short, they aspire to being therapeutic. Design of the built environment has significant potential to contribute positively to wellbeing in this context. To provide a genuinely therapeutic environment requires radical change from the typical institutional model for residential care. Architecture, by virtue of its capacity to influence human function and behaviour, including wellbeing, may be regarded as a driver for replacement of an outdated culture of care. From the perspective of the person with mid-stage dementia and onwards, many mundane tasks are rendered difficult, or impossible, by cognitive impairment; the built environment itself may further exacerbate this effect, if not carefully considered. It is possible to speculate, given the range and rate of evolution of technologies available today, that the therapeutic capacity of architecture can be enhanced further through rendering it capable of responding to the changing needs of a specific individual. This may prove valuable not only in deferring the impact of functional and cognitive loss on quality

of life, but extending the time for a move to supported accommodation. Embedded sensor networks possess further potential value in mediating the interaction between person and environment, in particular when an individual is no longer able to articulate needs, or to intervene on her own behalf to modify the immediate environment to achieve better fit. Sensing and wireless technologies, approached with an open and creative brief, present multiple opportunities to facilitate better functional and psychosocial fit. This thesis therefore consciously adopts a two-pronged approach to describing a model for enhancement of congruence. It appears, on closer examination, that in dealing with built environment, functional and psychosocial fit are frequently almost inseparable, and that many design interventions inevitably affect both. Chapters 5 and 6 describe how an integrated, technologically-enhanced architectural model, in the context of supported living for elderly people, might achieve this end.

In making dedicated living accommodation for elderly people, the complete design must address the specific needs of a user who may be both temporarily, and progressively impaired, and in all likelihood extremely stressed by the illness itself, and removal from a familiar environment of home. In this scenario, ability of the user to adjust the physical environment to achieve a high degree of “congruence” has decreased, and will continue, inexorably in the case of a person with dementia, to do so over time. While good design facilitates functional and psycho-social congruence, assistive and prosthetic environments enabled by ambient technologies and pervasive computing have potential to further enhance the effects of good design by addressing the changing deficit in fit brought about by a user’s changing needs, or varying environmental circumstances. Embedded technologies also have the potential to enhance congruence where the physical limitations of an existing setting act as a constraint. Truly person-centred design for this user-group will need to go well beyond what is currently considered to be “universally accessible”. The constantly changing attributes of the person with dementia present a significant challenge to the designer who aspires to genuinely “person-centred design”.

The description of the latter stages of AD, even presented briefly and functionally, is difficult to contemplate for many of us, even at a long remove. The reluctance to contemplate such an end is common, and understandable: it seems too harsh, too difficult and perhaps, all too possible. People often seem to assume that AD will happen to someone else. This is still reflected in policy and planning for dementia in many countries, not only in a critical lack of future planning, but also in a general reluctance to regard elderly people with dementia in the manner of “our future selves”. This may contribute to a continuation of care provision for elderly people in environments which are manifestly unsuitable, and a persistent and alarming lack of recognition of the urgency of the requirements for supportive accommodation for ageing population. Attitudes to cancer have undergone a seismic shift over that last generation: widespread diagnosis and prevalence have resulted in space for more open discussion, and sharing of experiences of a disease previously referred to only in hushed tones, and suffered in silence. While attitudes towards dementia may similarly alter in the face of the changing demographics of the 21st century, the “Silver Tsunami” is rapidly heading our way, and likely to swamp us as a society, if we insist on remaining uninformed and unprepared. The current blindsiding of the implications of demographic projections, in terms of lack of policy and appropriate provision, may well arise from a reluctance to acknowledge that the “person with dementia” may indeed be our future self. Roger Coleman has written at length on “designing for our future selves”, as an integral part of Universal Design (Coleman, R., Pullinger, D.J., 1993). On that basis design for elderly people with dementia should become part of the constantly-evolving paradigm of “Universal Design”. That said, the lack of any coherent or proactive approach to the making of appropriate places for elderly people to live safely and with quality-of-life, not only in Ireland, but also in the UK, is alarming. This attitude displays an unsustainable detachment from likely reality: if rates of dementia in people over 85 are thought by some experts to be over 50%, none of us can afford the luxury of assuming that it will not affect us personally.

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Chapter 4

Architecture as interaction design II: context

- **Demographic context**
- **Architectural context**
- **“I’m Still Here”**
- **Contemporary architectural models for elderly living**

Introduction

The architectural environment of care, and the total culture of residential care are inextricably interlinked: the physical reality of a building, from the general (siting, overall layout) to the specific (internal space planning, and down to the level of intimate detail) impacts continuously and relentlessly on how that building is used, and directs the possibilities and constraints for use. With this in mind, this chapter sets out to summarise and contextualise the current situation, in particular in Ireland, in relation to the provision of residential care for the elderly, with people with dementia, seen as a significant and potentially majority subset of the elderly residential care population of the near future. From a critical analysis, it attempts to find ways forward in relation to future provision, in relation to design of residential care for elderly people, grounded in a psychosocial view of environment, and its potential capacity to promote user wellbeing, as a prelude to the further proposal for the integration of environmental responsiveness, enabled by wireless sensor networks, into the architectural model.

DEMOGRAPHIC CONTEXT

Any description of the context of residential care for elderly people would be incomplete without reference to demographic context. Due to a combination of factors, Ireland's population is ageing, in line with European and global trends. The 2009 ESRI report entitled "Projecting The Impact Of Demographic Change On The Demand For And Delivery Of Health Care In Ireland", addressed issues of healthcare provision, arising out of projected demographic change from 2006 -2021 (Layte, R et al., 2009). Much of the information to follow is gleaned from the report. Ireland's declining fertility rate, decreased mortality rates and increasing life expectancies all contribute to the prediction that the "elderly" that is, people aged 65 and over, will continue to form a greater and increasing proportion of the population over the coming decades. This is in keeping with increased global life expectancies over the course of the 20th century, when the average US lifespan has increased by 30 years, from an average of 48 and 51 years for men and women respectively, in 1900 (CDC, 1999). In a lifespan of around 80 years, this is an enormous percentage increase. There are signs that the rate of increase in life expectancy in the US has slowed in recent years (OECD, 2013).

In Ireland, average life expectancy for men has risen from 71, in 1986, to 76.8, in 2006, and for women, from 76.8 years to 81.6 years in the same period. Net immigration between 1996 and 2006, predominantly in the 20 to 34 year age group, had the effect of temporarily "putting the brakes" on population aging in Ireland. This trend has reversed during recent years, with net emigration and unemployment in younger age groups, increasing the dependency ratio, but this has not yet been documented or analysed. Based even on the now outdated ESRI 2009 report, the proportion of population made up of people aged 65+ is predicted to increase from 11 per cent to 15.4 per cent, by 2021, with those aged 85 years and over increasing from 1.1 per cent to 2.1 per cent. The absolute number of older people is projected to rise, from 2009 to 2021, with the numbers of "very old old", i.e. people aged 85 or over, more than doubling from 48,000 to 106,000, and those aged 74-84 years increasing from 157,000 to 248,000. The proportion of older

people, now one of the lowest in the OECD, will rise to above the OECD average. While the total population is expected to rise by 21% to 2021, the proportion of population aged 65+ is expected to rise from 11 per cent to 15.4 per cent. The fall in the proportion of younger age groups is predicted to be most pronounced in Western and Southern counties; this in itself may present particular issues, where housing and care provision is required for scattered populations in rural areas. Household sizes are predicted to fall, and while women continue to live longer, the proportion (but not the number) of elderly women living alone is predicted to fall. The actual and projected increases in life expectancy in Ireland, and their impact on overall demographic trends are reflective of the situation in all developed societies, including Japan. Ireland's population is, in fact, ageing more slowly than many other countries: while the proportion of people aged 65+ is expected to rise to 15.4 per cent by 2021, the UK the proportion of over 65s has exceeded this level since 1985. In Germany this proportion was first exceeded in 1992. The 2009 ESRI report also concludes that the manner in which care, including long-term care, is delivered is unsustainable, even if the economic situation is excluded, given the nature of demographic change, and that healthcare needs to be both restructured and made more efficient to moderate the amount of investment required. There are profound implications for society in general, most particularly in terms of housing and healthcare provision, as an older population requires more healthcare provision than a younger one, and will have specific requirements in relation to housing, arising for age-related impairment and disability. If a change in attitude and policy was required on foot of the 2009 report, that need is even more urgent in the light of more recent demographic change.

Also significant, though largely overlooked in terms of its implications, including for design of care settings and products and environments generally, is that men continue to have lower life expectancies and greater morbidity than women (Kalben, 2003). As global and Irish populations age, we can expect women to predominate in older age groups, and for that trend to become more marked, at least temporarily. Apocryphal evidence from care homes in the UK suggests that

this disparity may be beginning to level out. However, in the US, where the demographic trend has progressed further, for a population of 85 years and over there are currently 100 women for every 49 men (United States Census, 2010). Designing for the elderly person of the near future implies that this increasing gender imbalance must be taken into account in the design of care environments. This may require revision of ergonomic standards at least. A further implication for research is a requirement to acknowledge the gender imbalance when involving users in the research process for designed care environments, and to take account of it in design recommendations which are based on ergonomics.

Ageing and disability

Disability, arising from both physical and cognitive impairment, including age-related disability, is the most significant marker for a need for residential care for elderly people. (Layte, R et al., 2009). This is a useful perspective for the designer in terms of designing for an older population.

Another notable feature of the ageing demographic is a consequent increase in the projected numbers of people with dementia, as the incidence of dementia increases with age. A recent report suggests that one-third of people aged 65 and over in the US die of, or with dementia (Alzheimer's Association, 2012). Mortality from dementia increases dramatically with age. When dementia progresses to mid-stage, it becomes in itself a cause of disability. The use of the term “mid-stage” is somewhat misleading for the layperson, as it appears to understate the deterioration in the person’s condition at that stage of the disease. Though disability rates for people at older ages are reducing, leading to a real increase in health status, the overall forecast is for an 18.6 per cent disability rate among Irish people aged 65 years and over in 2021, generating a forecast population with severe disability of 147,677, of whom, based on the 2009 report and on current provision, 35,200, or approximately one-third will require long-term residential care (Layte, R et al., 2009). The number of older people with severe disability is considered to be the direct equivalent, or proxy, of those requiring long-term care. Though rates of disability in older people are decreasing, rates of illness, such as

cancer, diabetes, and cardiovascular disease are increasing, in common with trends across the developed world. This is likely to result in an increase in requirements for acute bed capacity, in addition to housing and residential care. There is already a known lack of availability of “step-down care”, (i.e. of Community Hospitals), in the specific context of elderly care, so that acute hospitals are used when they are not appropriate, for example for convalescence. The needs of people with dementia in either such context must be carefully considered, especially given that acute hospital environments are very stressful for many people, and that such stress is likely to have an adverse effect on cognitive status of a person with dementia. Current government policy aims to reduce acute in-patient bed places to the lowest in the OECD, replacing acute care with “community care”, the preferred model for healthcare in Ireland. While it is suggested in the ESRI report that a “continuous care” model would provide appropriate support for patients as they move from acute hospital care to convalescent or assessment bed before transition either into long term care or back home, perhaps with community support, it may considerably more practical for step-down/respite care to be co-located with residential care, in larger settlements, minimising the disruption and stress to the individual involved. This approach is exemplified in the UK Close Care model (Habell, 2001), which allows a person to remain “on-site” with intensified care, including palliative care, when the need arises. This latter approach is more person-centred than that of continuous care, where step-down care is not co-located with supported housing or residential care.

The 2009 ESRI projections indicate trends similar to those in other developed countries. The oldest populations, and, by extension, the highest level of need, is found in Sweden and Japan. In an Irish context, net emigration in younger age-groups will inevitably reduce the number of younger persons available to act as carers, formal or informal. The full implications of this more recent trend for future care provision have yet to be examined at the time of writing. We also need look further than our current demographic projections to anticipate “possible futures”. Demographic analysis of the type undertaken in the 2010 ESRI report should be

extended to 2050, in order to make more useful projections. The proportion of “older old” people predicted to develop dementia also raises significant concerns about the pervasive nature of the disease, and must beg the question as to whether dementia should properly be considered a natural consequence of extending the human lifespan. The implications of such rapid change for society in general, as well as for people with dementia and their carers, are huge. In Ireland, and in the UK, policy-making has tended to avoid dealing comprehensively with the issue, very possibly because of the scale of those challenges, all the more so in the context of recent economic exigencies. A recent report from a UK House of Lords Committee rather bluntly concludes that the UK is “woefully underprepared” to deal with an ageing population, and that “social care and its funding are already in crisis”, both being required to successfully underpin ageing-in-place initiatives (Select Committee on Public Service and Demographic Change, 2013). It further concludes and that provision of adequate housing suitable for elderly people, and often with “linked support”, will be essential to maintaining independent living, and also draws attention to the inevitable need for increased healthcare for elderly people. A similar report is now required as a matter of urgency in Ireland. A National Dementia Strategy for Ireland is currently being developed, and it is imperative in this context that the disease should not be considered in isolation from the overall demographic and social context of ageing.

Ageing-in-place

“Ageing-in-place” is currently an assumed component of the Irish model of community care, and is also held as an aspiration in other countries, including the UK and the US. It is based on the belief that a majority of people will wish to continue to live in their own homes they grow older. However, it must be recognised, based on the demographic projections, including projected rates of disability, that it will not be possible to meet the needs of all elderly persons in the home, and also, that without adequate funding of proper supports, continuing to live at home is not a guarantee of quality-of-life. For example, without significant support, it is almost impossible for someone with mid-stage dementia to live alone.

From mid-stage on, continuous care is required, while people with more advanced dementia require significant amounts of one-to-one care. Similar concerns on the lack of suitable purpose-designed accommodation has been voiced by UK architect-researcher, Martin Habell, who maintains that care in the community cannot be assumed to have the same success for people with dementia as for elderly people in general and that current care home building stock in the UK is unfit for purpose (Habell, 2010).

Trends in household composition also influence projected needs for care: if an increasing number of elderly people live alone, there is, by extension no available source of informal care in the home setting. Non-availability of care in the home makes an earlier move to a care setting more likely, but also contributes to increasing social isolation. People living alone with dementia are at higher risk of self-neglect, injury and institutionalisation (Alzheimer's Association, 2012). It may be naïve, and even wilfully so, to assume that a majority of older people will in future live close to family supports, in suitable or readily-adaptable accommodation, and in locations where mobility and access to transport is facilitated. Community care and ageing-in-place models rely very heavily on presumptions that family members will be available as informal carers, despite the increasing participation of women (the traditional carers) in the workforce, rural decline, emigration from younger age-groups, and so on (Barry, Ursula, Conlon, Ciara, 2010). Death of a family carer seriously hinders the possibility of an elderly person continuing to age in place. Taking into account the fact that many carers of the elderly are now themselves classed as “elderly”, i.e. aged over 65 years, most often spouse or partner, it is timely to reflect on the consequences of embarking on such a policy naively, without taking account of its full implications. It is also implicit in ageing-in-place models that, to provide adequate support, in particular for a person with dementia, a variety of care workers need to travel to the person, requiring significant financial investment and coordination. If not, assumptions are again made that the person can travel, that transport is available, that someone is available to accompany them. If the real costs of ageing-in-place were considered,

including appropriate training for professional carers, loss of working time for family carers, the burden of stress (and often illness) on family carers, it might not be deemed appropriate in many cases, for the welfare of either the carer or the cared-for. Disturbingly, the 2012 “Care in Crisis” report from Age UK finds hundreds of thousands of people with dementia in the UK receive no state assistance, or inadequate care and support to facilitate ageing-in-place (Age UK, 2012). The situation is unlikely to differ greatly in Ireland. The actual and proportional increase in numbers of people who will develop dementia is perhaps the single greatest challenge to the community-based, ageing-in-place model. Given the role of stress in development and prognosis of dementia and other illnesses, it seems foolhardy to place such elderly carers in a situation which is likely to cause them ongoing stress and increase their own likelihood of chronic illness. Disability resulting from dementia, combined with living alone will inevitably result in situations where an elderly person rapidly arrives at the point where no level of non-residential care can provide adequate security. This view is borne out by the UK experience.

Notwithstanding the current emphasis on aging-in-place on policy-making, and to some extent, by extension, on availability of research funding, it seems inevitable that, given current demographic trends, there will be an increased demand for residential care, including supported housing, for elderly people, though it has become unfashionable or even politically incorrect to suggest this. The question then arises of the form such accommodation should ideally take, and how the current situation in Ireland compares with models currently considered best practice internationally. In many societies, there is some availability of supported residential accommodation for elderly people, in addition to similar accommodation intended specifically for people with dementia, though there is a paucity of such accommodation in Ireland. It has also lately been acknowledged that an elderly person may wish to move into purpose-built accommodation for a variety of reasons, including a person’s concerns for her own health, problems with property maintenance, and in particular, garden maintenance, fear of crime, and the desire for the security offered by supported living. (Appleton, N.J.W., 2002)

It is worthy of comment that a marked preference on the part of elderly people for ageing at home may be related in part to the huge inadequacy of traditional models of elderly care, including in Ireland, in meeting the needs of users. Notwithstanding this preference, while most people with dementia start by living with it at home, a majority will end by living, and dying, often with dementia, in a residential care setting. A considerable amount of the argument of the UK and Irish ageing-in-place models seems to revolve around the cost to the state of providing residential care places for a rapidly-expanding population of older people with dementia, and the deferral of a move to care for as long as possible on that basis. The prime consideration should, of course, be the question of what constitutes an optimal standard of care for people with dementia, and in giving elderly people a real choice as to how they live out their years. The UK and Irish models both rely on swingeing assumptions of the amount of care provided at no cost to the state by a spouse/partner or family living near an elderly person. It also pays scant attention to the cost, both financial and human, to those carers. “Caregiver burden” is a reality. The relationship between carer mortality and hospitalisation of a spouse is an acknowledged fact. US research demonstrated that 8.6% of men whose spouses were hospitalised for dementia died within the following year (Christakis, Nicholas A, Allison, Paul D, 2006). I have witnessed this particular event in my own family.

Technology and ageing-in-place

The assumption that new monitoring technologies will somehow obviate the necessity for residential care seems implicit in many policy models of ageing-in-place. The implicit presumption is that telecare, based on monitoring, will provide an omnipresent “magic wand” that will somehow remove the necessity for human carers. This assumption stands to undermine quality-of-life for elderly people, as much as to promote independence. Wellbeing involves far more than basic physical safety: monitoring systems offer very little more than this. A monitoring system can never replace human contact. If this is an implicit assumption in the ageing-in-place model, it is very far removed from placing the person at the centre. The best that might be hoped for is deferral of a move to a care setting, by provision of some

level of enhanced physical safety through use of remote monitoring and alarm systems. Significant amounts of research and development are still required in order to develop intelligent predictive systems even for monitoring purposes. The question also arises as to their suitability for use with a cognitively-impaired population. It seems unlikely that if all associated costs were properly considered, including the necessity for paid carer support, that aging-in-place as currently conceived in Ireland, will by any means provide a panacea. There is a suggestion that use of monitoring technology may provide little by way of safeguards for elderly people: recent research found that older users of such technologies, with multiple health issues, were equally likely to be admitted to an emergency room as those who did not use a monitoring system (Takahashi, P.Y., et al, 2012). This group also experienced an unexplained higher rate of mortality than a similar user group with conventional health care. Where such remote monitoring solutions are most likely to be proffered, rightly or wrongly, is in related to elderly people in isolated areas. The 2011 Census of Ireland shows that more than two out of every five people aged 65 and over lives in a rural community. This raises questions about the quality of life and physical and social isolation. According to the ESRI report, little is currently known about this population. The report, however, does conclude that *“The availability of remote monitoring and alarms should not be allowed to overshadow the very real need for provision of a higher level of care in other settings, including sheltered housing, nursing homes and long-stay hospitals.”*

ARCHITECTURAL CONTEXT

A brief examination of the historical context of care architecture for the elderly in Ireland is useful in this discussion, as it informs, and often continues to inform, the architectural typologies where elderly care takes place, and the evolution both of newer models of care, and their associated, and still largely prototypical, typologies.

Ireland's existing housing and residential care infrastructure is very obviously inadequate to support the projected level of growth in the elderly population, including in terms of how design of current building stock fails to meet user requirements. This is most particularly the case in relation to designing for the person with dementia, where specific needs arise in relation to provision of appropriate, psychosocially supportive care settings, to maximise independence and quality-of-life. While there is some recognition that future models of care must address psychosocial issues, the significance of design of the built environment in the achievement of such an aspiration cannot be over-emphasised. Design can facilitate or restrict; deficiencies in the built environment can further disable a person with cognitive and/or physical impairment. The most serious issue arising is that of many elderly people with dementia in Ireland and the world over, continuing to live in environments which are likely to actually exacerbate their condition, so disabling is the environment. The effect of environment on the person has been discussed in terms of theory and evidence in terms in Chapter 1. That concern is revisited in this chapter, in relation to existing and new architectural typologies of care.

Cruel Habitation?

Many Irish workhouses are still in use by the state, or have been used until very recently, to provide residential accommodation for elderly people, though this does not appear to be widely known, and certainly not publicly discussed. The construction of the first workhouses in Ireland followed the 1834 Poor Law Act in the UK, though workhouses had been constructed on a much wider scale in England and Wales prior to that date. In both the UK and Ireland workhouses were original

intended for use by those unable to work because of infirmity or illness. After the 1834 Act, workhouses were intended to deter their use by all but the most needy. One observer described the 1830s workhouse designs of architect Samuel Kempthorne as intending to be a "*terror to the able-bodied population*". An architectural contemporary of Kempthorne's described them as "*a set of ready-made designs of the meanest possible character*". Kempthorne's designs were succeeded by a model of linked separate blocks more familiar in the Irish context, mostly designed by George Wilkinson.

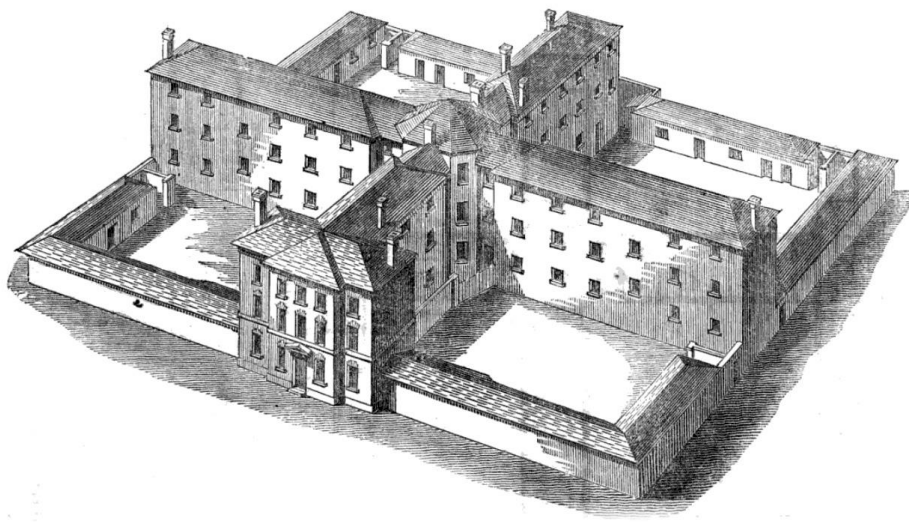


Fig 4.1 Typical Kempthorne workhouse

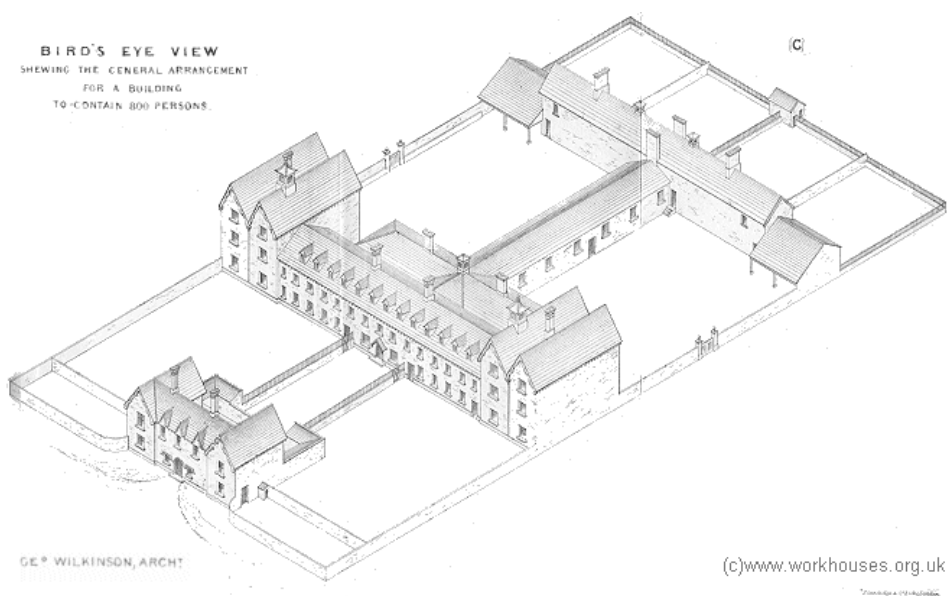


Fig. 4.2 Typical Wilkinson workhouse of linked blocks

In purely functional terms, even the physical layout of the typical Wilkinson workhouse renders it difficult to successfully adapt for use as a suitable contemporary setting for elderly care, once it is assumed that the multi-bedded ward model is an anachronism. Other than the principal block, the depth of the typical Wilkinson block is generally such that it is possible only to accommodate an inherently inefficient single-loaded corridor. Any adaptation designed to comply with contemporary standards, so including for single bedrooms, will result in a huge loss of bed-spaces, with a resultant requirement for additional new accommodation. It would seem logical given the lack of fitness-for-purpose, to replace workhouse accommodation wholesale with new, purpose-designed accommodation. This has been attempted on a phased basis in many locations. However, as funding has seldom or ever been available to construct replacement accommodation as one project, construction of these facilities tends to be phased, and so, new facilities almost invariably sit alongside former workhouse buildings on the same site. While HSE is conscious of the drawbacks to such an approach, and most often aspires to turn over workhouse buildings to administrative use, simple economic reality even in the Celtic Tiger years precluded taking the ostensibly more rational approach of replacing facilities in their entirety, other than at a small number of locations. While research has established a preference for ageing at home versus moving to care, it may well be the case that research outcomes are influenced by the lack of choice available, where almost the only alternative is institutional, nursing-home care.

Margaret Calkins has written that *“there is growing evidence that the design of the built environment, by itself and in combination with organizational policies and procedures has a direct and measurable impact on the physical and psycho-social functioning of residents with dementia”* (Calkins, 2009). If it is the case that built environment inevitably affects how users behave and how they feel, how can it be in any way appropriate to continue to house elderly people in settings with the inescapable hangover of their original design intention to deter, demean and control? This is without any reference to the attitudes and folk memory of

workhouses and their association with the Great Famine that prevail among a majority of Irish people. Research is required to clarify issues such as the possibility that a person might have preference to relocate to a supported community, given a choice, and also of the negative influence on personal preferences of the cultural values that Irish people in general are likely to attach to public sector elderly care provision, much of which is still located in Famine workhouses, or co-located with such buildings.

The term “Cruel Habitation” was coined by Martin Habell (Habell, 2009), a UK architect and researcher, to describe the state of much current accommodation for elderly people in the UK, in particularly for people with dementia. Often located in converted large houses, as is the case for many privately-run Irish nursing homes, it suffers from very similar deficiencies as the converted workhouse: lack of light, lack of outside access, no views out because of high windowsills, poor way-finding, and insufficient personal space. The accommodation, as is the case in Ireland, is essentially so unfit for purpose as to merit the appellation “cruel habitation”. The continuing use of such outdated buildings for elderly care in Ireland appears also to influence contemporary constructs of what might constitute an appropriate contemporary setting. For example, the recent HSE Teaghlach model seems to owe as much to what are regarded, in most Western countries, as outdated nursing-home models, as it does to the newer “household’ models, currently perceived as the preferred form of future residential care. In brief, the recommendation for a “household” varies from 8-12 people in UK and US models, but is 20 in the HSE model, in a 50-bed unit. No domestic household with which any resident is likely to be familiar houses 20 persons. Over-scaling of individual house units in this fashion is likely to cause problems with comprehensibility of the building plan. The Teaghlach allocation for a sitting-room is 30 m², insufficient to accommodate even half that number without creating an unavoidably institutional character. The overall allocation of 30 m² for the sitting-room does not facilitate any subdivision into smaller spaces, given the increasing size of appliances such as wheelchairs. The model is therefore too compromised to be held up as an exemplar. Aspirations

alone are insufficient for a designer to overcome the restrictions imposed by such spatial briefs. While HSE is no longer involved in procurement of buildings for elderly care, the “Teaghlach” model is now being used as a model for special needs care. Its ultimate rationale appears to lie entirely in the exigencies of economics, and available sites and buildings, rather than user needs. There is no identified preferred model for the private sector, though at least some private sector care-providers appear to be voluntarily constructing new facilities to exceed current HIQA standards, in order to “future-proof”.

There are similarities in the evolution from workhouses to current typologies in the US, Ireland and Britain, which in part result from a common heritage of UK administration. Provision in all cases has progressed from “warehousing”, in open wards, often in former poorhouses (this has been the case in the UK and US also) to hospital or nursing models, and latterly to newer and still largely prototypical “household” models such as the GreenHouse® model (US), and the model recommended by Better Care Homes. Research in the UK, where the cultural context of care is not dissimilar to Ireland (having evolved from Poor Law to Welfare State) also strongly favours clustered household models. The need for such models to be located in, as opposed to isolated from, existing communities is also stressed.

Designing for Functional and Psychosocial fit: a place to live.

A psychosocial approach to design indicates a preference for smaller residential units, for a variety of now well-researched reasons (Day, K., Carreon, D., Stump, C., 2000). Such settings permit greater resulting opportunities for personalisation and self-actualisation, as well as facilitating legibility and easier way-finding. Research has established that measures of patient well-being for elderly residents in smaller-scale settings were consistently better than in larger institutional settings (Calkins, 2009), with residents in smaller units having higher motor functioning and mobility, more friendship formation, less anxiety and depression, while those in larger units

had greater use of psychotropic drugs and antibiotics, and also exhibited more aggression. Research in Green House units, of 10 residents, showed a drop in participation in organised activities (Kane, R et al, 2007). It is curious perhaps that such participation is seen here as a definitive measure of wellbeing. Perhaps the result is simply a consequence of the freedom of a physical setting that afforded subjects the space to choose privacy, and have time to themselves. Another review of research has found that residents considered it important not to be forced to take part in social activities (Croucher, K., Hicks, L., Jackson, K., 2006). Personally, the prospect of being obliged to participate in activities which have never formed a part of my life, or in cherished activities, such as music and art, but in a fashion dictated by someone else, is a particularly potent vision of hell.

It should be by now obvious that residential settings for elderly people should be designed to maximise physical independence and usability by residents, but equally so that to date, they have largely been conceived of as places where old people are sent to die, rather than places where they go to live, and where poor standards are to be accepted without complaint on the same basis. It is also evident that the provision of a physically secure environment should not be prioritised at the expense of considerations of psychosocial support. Range and availability of spaces can impact very significantly on the latter (Archea, 1977). For example, if a care setting does not provide appropriate spaces to support a range of social interactions, residents are effectively restricted in the types of social interactions available to them. Most commonly, there is no available, and appropriate, space for intimate, one-to-one social interaction. Visitor's rooms belong no more to an individual than to a group. There is a qualitative difference between a sitting-room in one's own house, and a shared sitting room in a care setting, and a yet greater difference, a quantum gap, between the private domestic social space of a sitting-room, and the types of large-scale spaces common in Irish and international care settings. The entire culture of care appears to be still coloured by a view of elderly care homes as a place people go to die, not where they go to live out their days in a supportive environment that caters to their total needs, psychosocial and

functional. There are of course, exceptions, such as the Cheshire Homes sheltered housing schemes, but these do not currently accept people with dementia. The need for psychosocially supportive environments is absolutely critical in the case of people with cognitive impairment from dementia, often overlaid on other age-related physical impairment. Design guidelines and exemplar models therefore must take into account the detailed interaction between person and care environment at all levels, from siting, to layout and way-finding, through to the detailed design of spaces and objects, most particularly design of the resident's own personal life-space. Provision of single-room accommodation for all residents should be regarded an absolute necessity. Consideration of provision for couples to continue to live together in care must also be broached, including where one chooses to accompany the other to continue his/her role of carer, which is not currently possible. While it is recognized that a supportive architectural environment must be complemented by a non-institutional model of care-giving, it is also likely that, if we continue to build institutional-style accommodation, the physical environment of its nature will serve only to impede delivery of psychosocial models of care. To quote Margaret Calkins: "It is time we stopped allowing buildings of this (institutional) style to be built". (Calkins, 2009)

"My wallpaper and I are fighting a duel to the death": Conflicts between aspiration and reality in residential care design for elderly people

If the built environment is inextricably linked to the culture of care, then it is difficult, if not impossible, to provide truly person-centred or "psychosocial" care in an institutional environment, which already places additional burdens on carers and residents alike by virtue of its lack of fitness-for-purpose. By the same token, the care-provider's view of the individual (patient vs. person) colours the entire culture of care, including how design briefs are formulated, and in particular in relation to allocation of space. Despite the best intentions of the designer, (s)he may find herself obstructed by lack of spatial allocation, such as is necessary to properly cater for a range of situations and activities needed to fulfil psychosocial needs. An overweening emphasis on infection control frequently leads to situations where it is

virtually impossible to recreate a domestic atmosphere, for example, precluding, in Ireland, the use of personal furniture. In public sector settings, it is usual for the designer to be restricted to a choice of hard, and frequently synthetic, surfaces only, in the interests of cleanability. This in turn restricts the palette of colours and materials available for specification, which are deemed acceptable by the service provider. Aspirations to “avoid glare” remain aspirational as a result of the perceived necessity for specifying almost exclusively hard, wipe-clean surfaces, which will tend to reflect rather than absorb light (Torrington, J. M., Tregenza, P. R., 2007). The available choice is often one between “shiny” and “less shiny”, by the very nature of materials such as laminate finishes, and sheet flooring. It can be made impossible, in practical terms, to specify natural materials. Hard surfaces also reflect sound; this makes for noisy spaces, where it is often difficult to distinguish speech clearly. It has been said that noise is to people with dementia what steps are to wheelchair-users. Hearing loss and cognitive impairment lead to confusion, discomfort and even alarm arising from ambient noise conditions, including normal “household” noises (van Hoof, J., et al, 2008). An effective restriction on practicing designers to use of hard finishes in residential care for elderly people appears to be courting disaster from the perspective of environmental fit. An embargo on soft and tactile materials pushes such environments towards complete exclusion of a multisensory approach, regardless of any written policy, and with it, any pretensions towards being genuinely psychosocially supportive. An holistic design approach, which might also be described as architectural, suggests that every resident’s room should incorporate multisensory aspects, and that use of all the senses in interpreting an environment should be an everyday possibility, not just something restricted to visits to a special room, as is common in special needs care, and currently being introduced into care settings for dementia patients. Whatever about the known benefits of using a multisensory room, how can it possibly be argued that the user’s living space should be hard, unfamiliar, and unwelcoming, and a special room the only respite? Oscar Wilde’s last words are said to have been, *“My wallpaper and I are fighting a duel to the death. One or the other of us has to go”*, referring to his room at the Hotel d’Alsace. They may have held rather more than a grain of truth.

Client interpretations of design guides for dementia care and universal design can also be over-rigid, and may stifle innovative design solutions. Previously-used design solutions based on limited research should be viewed as one of many possible answers, not the solution in every situation. Even then, the existing evidence-base is still small. In the absence of considered design input, over-literal interpretation of narrow research outcomes, for example, those which recommend use of bright colours to aid in identification of important objects, can lead, if not used in a considered fashion, to an over-coloured, and over-stimulating environment, a sort of “McDonald’s syndrome”, which may actually exacerbate dementia symptoms through creating visual confusion. Even McDonald’s has move on from a “fast-food” interior design approach, which aimed at rapid turnover, to one which hope to entice customers to stay on the premises, though use of softer lighting and colour, and more natural finishes.



Fig. 4.3 There’s a difference at McDonald’s...

Design guidelines are rarely as restrictive as they might seem at first glance, and usually avoid being over-prescriptive, though it is not unusual for care-providers themselves to impose narrow interpretations of guidelines. Much research on colour, for example, is not carried out in the built environment. Built environment recommendations derived from such research are often naïve when applied in the real world, or unnecessarily restrictive. The most effective way of gauging the success of a design intervention is through post-occupancy evaluation. At the moment in Ireland there is little more than anecdotal evidence of success. I can state, as an experienced design professional, that on occasions where I have

applied a more intuitive approach to design of care environments, based on limited research review, there has been little other than positive feedback, despite some apprehensions on my own part, for example, about use of particular colours. Sometimes when it looks right, it is right. The role of a thoughtful and informed designer should not be underestimated. On the research side of the fence, demonstrating in a convincing manner whether or how design has any beneficial effect, is extremely difficult, given that research methodologies tend to the reductive, while design, in particular architecture, synergises many factors to create a successful environment. It is nigh impossible to separate out the different factors, and perhaps not very useful in the long run. Answers may ultimately be found in research on, and in live environments. John Ziesel, among others cautions, advocates a holistic approach to the design of environments for people with dementia, so that the entire environment becomes comprehensible, and acknowledges that satisfying all the requirements on a list of recommendations is not any guarantee of success (Ziesel, 2005) (van Hoof, J., et al, 2008). Given the available research, and theory in environmental psychology, it seems a contradiction in terms to suggest that a “psychosocial model of care” can thrive in an environment which tends towards sensory deprivation and de-personalisation. Yet it is this, and little more, that current regulatory environment appears to permit. Facilitating environmental congruence demands considerably more than lip-service. These same restrictions on design and specification routinely apply to step-down and acute hospital care, where at least they may have less potential for damage as the average length of stay is far shorter than in residential care. How much of the extra burden of care created by the lack of congruence, both psychosocial and functional, then falls on the carer?

The situation in Ireland in relation to both current and future provision of suitable accommodation for elderly people could be described as alarming at best. There is little evidence of ongoing procurement of residential care buildings on the scale likely to be required, or of any coherent move towards developing new models of care, with support in policy. HSE is no longer commissioning elderly care homes,

except where substandard accommodation is to be replaced. If the entire provision of care accommodation is to be devolved to the private sector, stronger direction and control is required than is currently available. On the basis of research and comparison with other models, existing HIQA space standards for new facilities are too low, most particularly for bedrooms, and insufficient for any degree of future-proofing. There are known, and frequently insurmountable, conflicts, for the architect, between existing statutory requirements, and the desire for a household-type care setting. Some of the worst are in dealing with Fire Regulations, when residential care is dealt with largely as if it were a hospital setting. For example, the insistence on door closers on all doors to a corridor can necessitate closers on toilet doors, for reasons of fire safety, which a resident simply cannot open, and which cannot, for reasons of privacy, be left held open. There are *no* door-closer products that will meet this need, and simple laws of mechanics dictate that there are unlikely to be. The solution, if a genuinely psychosocially supportive model of care is to be adopted successfully, is to draw up specific regulation for such building types, which better balance considerations of security, congruence, and user characteristics, based on full and rigorous analysis of benefit and risk. Similar comments apply in relation to infection control, when over-zealously applied. In the face of such constraints, a designer can be completely disempowered in relation to creating a user-centred solution that also meets regulatory requirements. The regulatory environment should not be permitted to eclipse the view of the end-user. “People, not patients” must be the watchword.

“I’M STILL HERE”

Having practised as an architect in healthcare design for many years, I was struck very emphatically by the differences in perceptions of the needs of elderly people in care, in contrast to perceptions of users with “special needs”. In the latter case, emphasis was inevitably on “quality-of-life”, and personal development. By contrast, the focus for elderly people seemed to fall largely on functional provision. Even where more than basic provision was sought by hospital management and

nursing staff, those aspirations were effectively obstructed by design briefs, which were inevitably overly restrictive, particularly in terms of space allocation. In turn, the culture and quality of possible care are unavoidably coloured by the physical environment of care. Promotion of personal independence cannot successfully take place in a built environment that, by its very nature, mitigates against functional and psychosocial congruence. The consequences are seen in “disturbed behaviours” among persons placed in care, which are often, and lamentably, countered by the administration of psychotropic drugs. Therefore any model of care which purports to be “psychosocial” must, of necessity, simultaneously address the issue of the physical environment, not only because of the known influence of environment on wellbeing, specifically as a source of stress, but also because of the influence of physical environment on delivery of appropriate care.

Even where intentions are ostensibly the best, design outcomes are often strongly coloured by continued commissioning and use of what are essentially institutional models of care, where scant real regard is paid to the person who should be at the centre of the model. Decisions about care, regarding what is right, wrong, or better, often appear to be persistently informed by an institutional view of the person, which renders them as something slightly less than a whole person, with individual characteristics and needs. What must be remembered that even in the case of significant physical and more particularly, cognitive impairment, is that that the “patient” is one aspect of the complete person, with all their memories and experiences. While behaviour may regress to that of a child, or an infant, this person is still not a child. They must be regarded as not just the outward aspect or set of challenges to care and design that they now present, but also, and critically, as the sum total of everything they were before over the course of their lives. To borrow John Ziesel’s phrase, the plea of the person with (Ziesel, 2010) is *“I’m still here”*. The essence of the person remains, and must be actively sought, and valued in the culture of care-giving. Care of elderly people invariable and unavoidably implies care of people with dementia, or people who will develop dementia while in care. It is not an issue that can be put to one side either in the proposals for new

care models, or their embodiment in the built environment. Given the existing situation, and predicted demographic trends, true consideration of the user must be an absolutely central concern in how we design environments for elderly people, at home or in care. Elderly people and elderly people with dementia are not “two tribes”. This is not to say that every elderly person will develop dementia, but that the incidence of dementia rises with age, and is significantly higher in the “very old old”. The onset of dementia is very often a marker for the move from living at home to living in a supported environment. There is huge support for “ageing-in-place” in terms of interest and funding; yet how much does this ignore the reality and stress of living in an environment outgrown in terms of congruence, or care to examine the real reasons as to why a majority of elderly people are resistant, if not downright fearful of a move to residential care. Why do we continue to design and build care setting that frighten people? How should we design new residential accommodation that caters for the needs of elderly people, especially those with dementia? What contribution can emerging technologies make?

Suggested Approaches: community-based care

Notwithstanding the current emphasis on aging-in-place on policy-making, and to some extent, by extension, on research funding, it is still a certainty that, given current demographic trends, there will be an increased demand for residential provision, in various forms, for elderly people. The question then arises of the forms it should ideally take, and also of how the current situation in Ireland compares with models currently considered to represent best practice internationally. On the basis of demographic predictions referred to earlier, it is reasonable to suggest that *all* new residential care facilities for older people should be designed so that people with dementia can successfully live in them, rather than, or in addition to constructing specific dementia care units. A person-centred approach suggests that a resident might be required to relocate, but ideally only within the confines of a site, or alternatively, be facilitated in always remaining in the same accommodation, depending on the chosen architectural model. Elderly people who do not have dementia may not benefit from being co-housed with people with

dementia; this needs to be considered in any proposed design solution (Wiltzius, S F, Gambert, S R, Duthie, E H, 1981). A solution that includes for flatlet-style accommodation, such as that proposed by Jenny Willatt in “Design as Therapy” (Willatt, 2011) might largely circumvent this issue. An inclusive approach, coupled with a community-based clustered household or flatlet model, perhaps with onsite respite and palliative care, (as in the UK Close Care model) (Habell, 2001) facilitates ageing in supported accommodation, without further need for a person to be moved offsite, and away from their community, as their condition deteriorates. The level of support provided onsite can be increased as and when required. If clinic facilities are provided onsite, they might also be made available to elderly people in the surrounding community, establishing and fostering relationships within the community, including with potential future residents. The Onni Centre, in Finland, adopts this approach, which aims to comprehensively address both the existing and anticipated care needs of the elderly resident. It should be noted that the stress associated with moving location is almost certain to exacerbate dementia symptoms. Recent research from Northern Ireland indicates that prescription of psychotropic drugs for elderly people more than doubled (from 8.2% to 18.6%) after they were moved to a care setting, and that rates of prescription of such drugs for elderly people in care settings overall was *twenty times* that for people living in the community. (Maguire, Aideen et al, 2013) Given the demonstrable unsuitability, and institutional nature, of a majority of care settings as currently constituted, it is almost inevitable that some of this apparent increase in need for medication may arise from stressors of environmental origin. The extent to which this perceived need for over-prescription is due to environmental stressors, or to pathologising of behaviours, which might not be regarded as “challenging” in another physical context, is unknown. There is a real paucity of other research the consequences *to the person* of a move from home to residential care, though there is research on the effects on carers.

The ESRI report refers not only to the changing demographic as a predictor of care need, but also of increased service expectations from an increasingly vocal demographic, and an increased need for services for previously unmet needs. As a

lobby group, older people in the US have become both vocal and influential in expressing their needs and preference for a variety of services. It would seem likely that Grey Power will also arrive, albeit belatedly, on these shores, as older people come to represent an increasingly significant market force, including for residential care. At the same time, we appear to be at a critical point, where if heed is not paid in very short order to impending demographic change, existing care provision will be completely swamped by what has been referred to as the Grey Tsunami.

CONTEMPORARY ARCHITECTURAL MODELS FOR ELDERLY LIVING

The MyRoom model is conceived as part of a model for communal living based on recent architectural and care-giving trends in the United States and Europe. In the US, there has been a gradual progression from de-institutionalisation (as in the Eden Initiative), through quasi-domestic residential models such as the Evergreen Community and Meadowlark, from facilities with identifiable internal neighbourhoods, to third-generation facilities consisting of grouped stand-alone households of around ten residents, epitomised by the Green House (Fig. 4.5). The current most-favoured architectural model for elderly care in the US is the “clustered household” model, where 8-12 residents share a domestic-scale dwelling, with a number of dwellings clustered together, ideally set in an existing community. The Green House model represents the latest evolution of this typology. Residents living in smaller-scale units show a much lower incidence of disturbed behaviours, perhaps unsurprisingly, given the significance of the influence of environment on well-being which both theory and observation would suggest. It is worthy of comment that such any such model should more correctly be regarded as “quasi-domestic”: it is, after all, not generally taken as the norm to share one’s home with complete strangers. Even in student housing, there is usually some degree of choice regarding housemates, as well as far greater choice of being away from the house by personal choice. The newer models of care focus on the needs of the resident, rather than carers, or traditional nursing models. The Green House concept furthermore embraces smart-home technologies; for example, in order to minimize intrusion resulting from monitoring. Significantly, architecture is recognised as a driving force in culture replacement in care of the elderly (Baker, 2007).

European models included here, for comparison, include Finnish, Dutch and UK models of communal residential architecture, as examples of good practice. Finnish models include apartments and group homes, such as “Willa Viola”, the Willa Home, Tampere, and the “Onni” Care Centre at Pukkiila (Fig. 4.6). Here, communal living is in apartments of 40-60 m² with living room, bedroom, kitchen and

bathroom, but also with access to a communal sitting-room, dining-room, kitchen, service facilities and staff rooms. Residents have personal living-space, with the option of communal facilities as and when need arises. The Onni project is community-based, and also incorporates day-care facilities and community healthcare facilities, in what might be described as a “one stop shop” approach. De Rokade, in the Netherlands, designed by Arons en Gelauff Architecten, is a multi-storey residential care apartment building, where the internal layout and individual space allocation within the cruciform floor plan is varied from floor to floor, depending on the specific needs of the user: for example, to cater for a single person, or alternatively, for a person who needs care, but lives in a family situation.

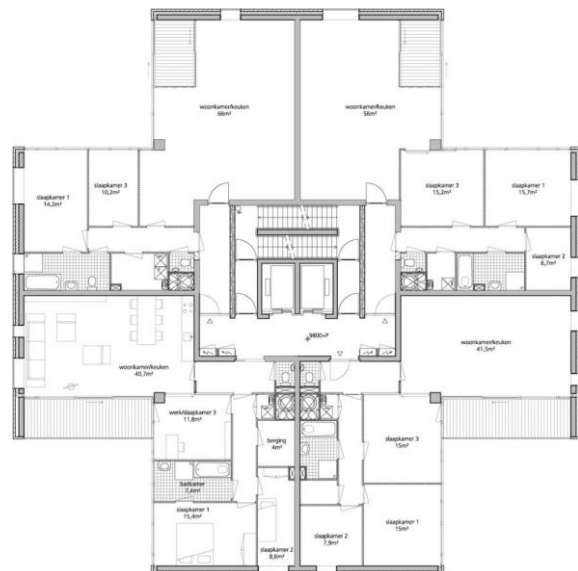


Fig. 4.4 Die Rokade (Arons en Gelauff Architecten)



Fig. 4.5 The Green House ®

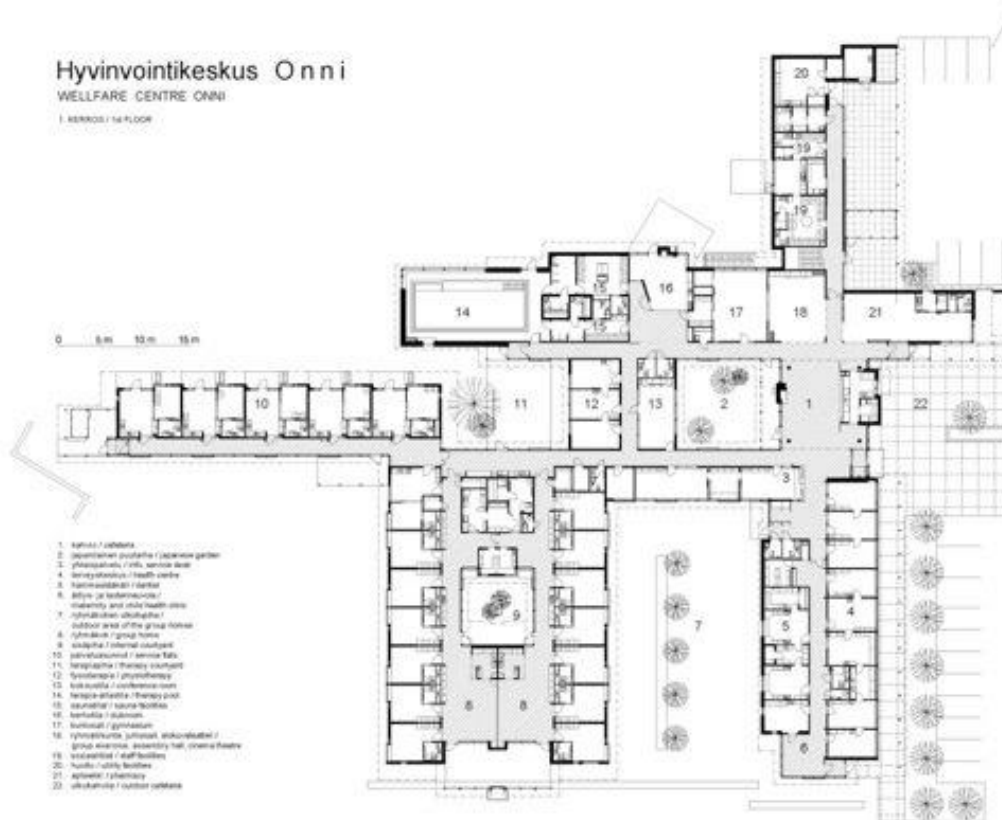


Fig. 4.6 "Onni" Welfare Centre: Plan

In the UK, as in Ireland, a majority of residential care for elderly people is provided by the private sector: 61% of elderly people in long-term care in 2008 were in private sector accommodation (Barry, Ursula, Conlon, Ciara, 2010), most of it in buildings which are not purpose-built. This is a particular issue where they are expected to cater for residents with dementia. There is a slow move in the UK towards smaller-scale domestic-type and clustered residential settings, such as the “Close Care” model. Close Care and similar models begin to recognise elderly people as a market force, and are geared towards their specific needs. The Close Care model was developed specifically as an assisted living model for elderly people, with Martin Habell architect and researcher. It consists of either a single block, or individual dwellings arranged “campus-style” with a shared resource block. The first built examples broke the rigid distinction that had previously existed between nursing-homes and private retirement housing schemes, a distinction which still persists in Ireland. The private sector is at liberty to break such conventions; the public sector still perpetuates an unhelpful distinction between supported housing and other residential care, which are within the remit of different government departments. In the public sector, residential care falls generally under the aegis of the Department of Health, while sheltered housing is dealt with by Local Authority housing departments, and also through the DHSS in the UK. This is more of an issue than might at first appear to be the case, as the distinction between the two does not facilitate meeting the changing needs of many elderly people. “Close Care” has become a generic term for assisted living schemes with a co-located nursing-home. The model evolved from Martin Habell’s earlier designs for elderly care, which consisted of 10-14 bed units clustered around a shared central courtyard, dating from the 1980s, but also from strong convictions about the unsuitability of previous design and care approaches.

While the Close Care model offers better quality of life for elderly people, the difficulty in finding sufficient suitable sites in time to meet an already urgent need may necessitate focusing instead on provision of urgently necessary bed-spaces in a purpose-built model, which is effectively an ESMI (Elderly Severe Mentally Ill) unit. This approach offers advantages in terms of construction costs, more rapid

procurement, and numbers accommodated on a site. On that basis, Habell has also developed specialised dementia care units, which incorporate design features specifically intended to improve ease-of-use and quality of life for residents (Habell, 2013). These include a comprehensible plan, multiple cuing, an enclosed garden or “pairidaez”, a “Memory Trail”, which moves from inside to outside, and emphasis on light, including a daylight room with therapeutic lighting. The ideal model remains nonetheless that of small-scale units, which incorporate those same characteristics, achievable through multiple design approaches.



Fig. 4.7 Willicombe Park, Tunbridge Wells (Martin Habell/Maybourne Projects)

The European models, on the whole, show a greater concern with provision of personal space than the Green House concept, as a consequence of their being based on self-contained living-units in a supported setting. The issue of flexibility of living-arrangements, for individual needs, or over time is also addressed. The comparison of exemplar models also serves to illustrate that design does not provide any single definitive solution, and that residential models are inevitably influenced by cultural context.

Residential models derived from research

Recent hypothetical care models, derived from research, also display shared concerns about the availability of personal social space, and environmental fit in general. The UK “Better Care Homes” (NHS/RCA) model (Helen Hamlyn Centre, 2011) is described as a “cluster” model, though this is not evident from the actual physical disposition of spaces, which does not clearly articulate discrete house-scale units, though the model extensively describes detailed design. This may be a consequence of an apparent lack of architectural input into the design model, or a conscious avoidance of a prescriptive design approach. Though aspiration towards domesticity is considered, the model, as for the Green House, is essentially quasi-domestic, in part due to its scale, and also the expectation that communal living for elderly people continues to imply sharing of personal living-space with people who are not family members, and are not personally chosen. However, this is compensated for by the provision of additional space in the user’s own room. Space standards and room layout closely resemble those of the thesis room model, though arrived at through different methodologies. The Better Care Homes model was arrived by group research, on the basis of a broad methodology; MyRoom adopts a design-based approach based largely on ergonomics, and existing design experience from practice. Though it is influenced by research findings on environmental fit, and factors promoting wellbeing, as a design exercise it is relatively simple.

Jenny Willatt’s model for dementia care, in “Design as Therapy” (Willatt, 2011) comprises small apartments/flatlets ranged around secure shared landscaped spaces, with linked shared facilities. This approach is both more architectural, and more legible to the user as a familiar domestic urban/residential typology, which operates at a variety of scales. It has elements in common with the author’s own 1997 residential care scheme for residents with moderate to severe mental learning disabilities (Caomhnú), which is made up of linked house units separated by courtyards, but is smaller in scale. Willatt’s model makes a concerted attempt to address many of the issues highlighted in the literature review for this thesis,

arising from similar concerns for use of “design as therapy” or, in other words, salutogenic design. This is addressed at different scales, from overall planning, through to the internal layout of individual rooms, and their relationship with external spaces. While her research sources may differ, there is a very close correlation with this thesis proposal, in identified environmental preferences, for example, for connections with nature, multisensory aspects, and seasonality, and in the sizing and internal arrangement of individual flatlets.

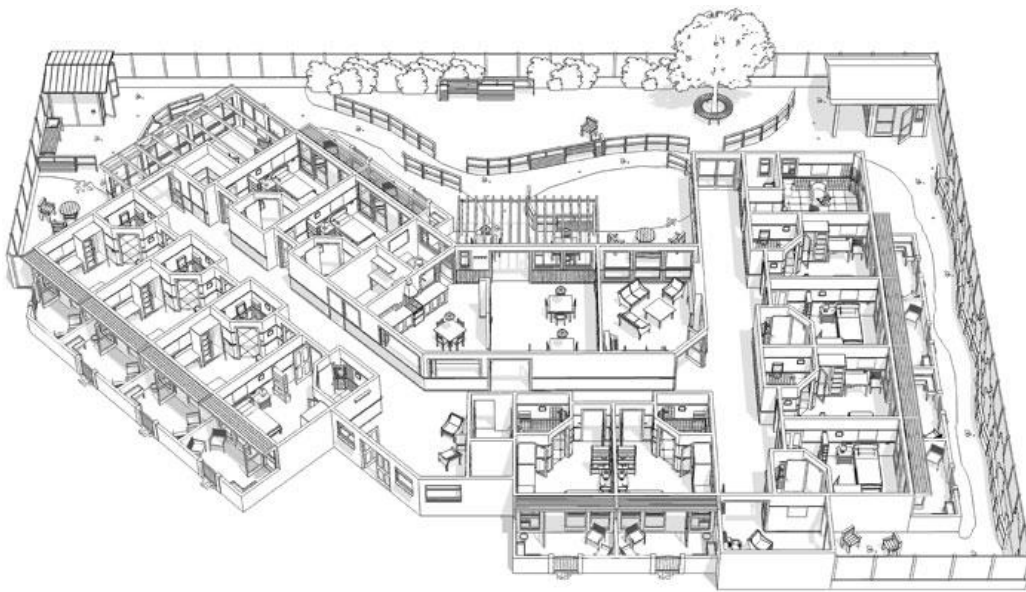


Fig. 4.8 “Better Care Homes” Model

www.bettercarehomes.org

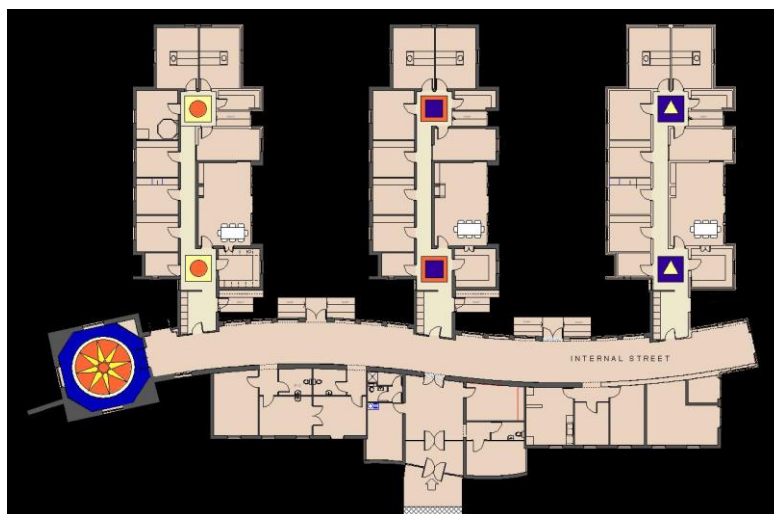


Fig. 4.9 Caomhnu Residential Care Units, Kilkenny, Ireland (Dalton + O'Donnell Architects)



Fig. 4.10 “Design as therapy” model (Jenny Willatt)

Architecture versus technology?

Architecture for care settings, and consequently, the design of a template for architecturally-embedded interaction in care settings, raises particular issues use of technologies. Fitch (1975) has argued that architecture may be seen to have contradicting requirements of functional versus formal criteria: *“The more complex or vital a process to be housed, the more critical the contradiction becomes. Hence the architect’s freedom to create necessarily diminishes in inverse proportion to the criticalness of his task”* (Fitch 1975, p.25) Fitch cites the example of an operating theatre as an extreme case, where functionality prevails to the exclusion of other design considerations. More recent healthcare design models have recognised that there are negative aspects to patient outcomes in healthcare environments which are designed with only the functional/technological in mind, and that regardless of the functional necessities of high-tech healthcare buildings, it is no longer acceptable to ignore the significance of user experience, and the negative impacts of the late-20th-century approach to healthcare design. The change in attitude arises out of an ongoing move from institutional and purely functional models, to

more patient-centred ideas of care, cognisant of the significance of environmental design in promoting wellbeing. Contained in this aspiration is a return to concerns which were highlighted around the time when modern nursing practices emerged but which have since become lost in a welter of medical technologies, where care architecture, in many respects, has too often been reduced to little more than a container for expensive and sophisticated equipment. Far older architectural models for healthcare buildings overtly concern themselves with basic aspects of the built environment which are considered to be beneficial, such as sunlight and fresh air, both referred to by Florence Nightingale (Nightingale, 1860). More recently, the TB sanatoria of the early 20th century offered patients single rooms, with direct access to outdoors, facilitating enjoyment of fresh air and sunlight, for therapeutic purposes. Somewhere in between, the patient has become commodified, or reduced to a set of symptoms. This becomes highly problematic where the domination of overt medical technology in itself becomes a source of stress for the patient which is highly undesirable, given the role of stress in illness. The existence of post-ICU syndrome, and psychosis, has now been identified. Though in part resulting from illness, and the trauma of medical intervention, environmental factors, such as sensory deprivation, constant light levels, disorientation, stress and intrusive monitoring are all acknowledged as contributing causes. For that reason, many of the proposals made in the MyRoom model also have application in an acute hospital scenario. Though the influence of architecture and environmental design in acute healthcare environments is now well-recognised (Devlin, Ann Sloan, Arneill, Allison B, 2003), change is slow to happen, and often impeded by organizational inertia, as well as continued use of older, and therefore often inappropriately-designed building stock. The issue of environmental influence on residents in long-term care settings has been given far less attention to date. In both acute and residential care, the ability of the user to adjust to the physical environment, in order to achieve a high degree of "congruence" has decreased, temporarily or permanently. While residential environments might not always present themselves as so immediately as quite as alien, or stressful, as acute hospital environments, (though many differ very little from hospitals), the fact that residents are exposed to potentially detrimental environments for months or years

could signal even greater and cumulative impact on wellbeing. The analysis of the functional and psychosocial needs of an elderly person with dementia, and of the physical reality of a majority current residential care settings, leads to the inevitable conclusion that a majority are unfit for use, so strongly do they mitigate against the possibility of environmental congruence. The review of elderly user needs, and consideration of concepts of congruence in this thesis, strongly bears out that viewpoint, as does the particular significance of environmental stress for the person with dementia.

This thesis proposes that ICT, specifically in the form of embedded sensing systems and applications, should be used for environmental enhancement, rather than solely for functional or clinical purposes. In this manner it may offer compensation, both for negative effects arising out of functional constraints in built form, and more specifically, for loss of ability, whether temporary or permanent, on the part of the end-users of care architecture, whether that user is patient or resident. While it would seem self-evident that end-users in healthcare scenarios are more vulnerable to stress of environmental origin than “average” users, as a result of illness or impairment, this seems to be blindly overlooked in many instances, not always by designers, but also by medical institutions as commissioning bodies. To put it very plainly, hospitals and nursing-homes can, and do contribute to making people feel ill, by firstly not affording environmental conditions conducive to wellbeing and recovery, and in the case of long-term care, by failing to provide environments consistent with the particular needs of vulnerable user-groups, and similarly failing to adequately support wellbeing. The design of an acute care environment must address the specific needs of the user who is unwell, and likely, as a result, to be temporarily incapacitated or immobilised, as well as being stressed by the illness itself, all in addition to removal from a familiar, to an unfamiliar, and highly-technologized environment.

While good design can facilitate functional and psycho-social congruence, assistive and prosthetic environments enabled by ambient technologies and pervasive

computing have potential to further enhance the effects of good design by addressing the changing deficit in fit brought about by a user's changing needs, or by varying environmental circumstances. Embedded technologies also have the potential to enhance congruence where physical limitations of an existing setting act as a constraint. The approach in this model is two-pronged; that is, it consciously deals with both *functional* and *psychosocial* considerations in interaction design integrated into architectural design. This is achieved through an exploration of a design template for responsive healthcare setting, seen as a specific localised model of responsive architecture. The model explores the potential of wireless technologies to facilitate, in a new way, the particular relationship between the person and her "personal life space". Such an approach seeks a closer understanding of how people function in the built environment. It does not consciously seek to invent new physical typologies, but rather to increase their potential functionality, defined to include "user-friendliness" as a measure of true functionality. This invariably leads to the proposal for inclusion of affective computing, as a necessity in any model for architecturally-embedded responsiveness in such a context. Without it, the model would fall short of much potential to recognise or address issues of psychosocial fit. In this, it mirrors the evolution of ICT itself, which is moving beyond notions of acquisition and modelling of data, and becoming more concerned with usability, and useful interpretation of "big data". This change of attitude is evident in the ease-of-use of "Web 2" technologies, where information and social networks, informed by personal information, are readily accessed by web-enabled, user-friendly handheld devices, such as the iPhone and iPad. One might ask what is the relevance to architecture: it is that interface design does not only concern itself with technologies, but equally with the user, and the minutiae of the possible interactions between that user and the system on the other side of the interface. As such, architecture reframed as interaction design, with the built environment as the interface, has potential to influence behavioural outcomes, described by Lawton as a function of the unique interaction between the individual and her environment (Lawton, 1975). In the context of this exploration, the protocols for design of web-enabled systems and applications, as well as being successful standalone technologies, are a significant point on the route to

environmental embedment, and to some extent may serve as models. On a practical level, Web computing protocols can be used as a basis for embedded local networks, but may prove to be less appropriate as design of embedded systems progresses.

Ubiquitous computing and access to information: issues of security, safety, and communication

Issues of ethics are often raised about the sensing of vulnerable subjects, such as elderly people with dementia, in particular with regard to applications which require continuous sensing, and use of personal data, which raise issues of privacy and intrusiveness. Many of those objections to ring hollow in the context of the reality of the restrictive nature of much existing residential care, where ensuring resident “safety”, in a very narrow sense, has hugely negative impacts on psychosocial congruence. Research on resident safety is generally couched in terms of reduction in falls, and of unaccompanied egress. Where fears are expressed about privacy and social control for a vulnerable elderly user, they must be considered in the light of the manner in which conventional care environments are already often very highly-controlled. This is often in order to minimise risk of harm or injury, but at the same time renders such environments fundamentally unsupportive of psychosocial congruence. Common examples of such restrictions, though they have not been perceived as such until very recently, if at all, are the enforced socialisation of the common sitting-room, in the absence of private social space, and restrictions on free access to external space. Restriction by actual physical restraint is still in use, though now considered unacceptable, and still surfaces as a result of inspections. Where sensing applications, such as RFID, are used to control access and egress, they are invariably selectively filtered so that residents are restricted from independent egress to outdoors, while staff and visitors come and go freely. Despite the common imposition of such physical restrictions on the resident, it is not unusual, the world over, for persons in care to leave a care setting unobserved, and only to be found days after, sometimes dead.

A quick internet search throws up many such news stories. Recent cases in Ireland include the death of an elderly person who left a nursing home, and, despite a frantic search by family and police, was killed in a fall a couple of days after, having wandered some distance. GPS tagging might have avoided all this; not only that, but a system can be designed to identify location through GPS only when a user is a certain distance from “base”, or when triggered at an egress point by an RFID tag, or when it proves impossible to locate someone after a reasonable length of time. The “safe” boundary for the resident might then shift from the external door, to the gateway to the property, and thus the domain to which the person has independent and secure access can be allowed to expand considerably, giving free access to a safe outdoor area, which is considered highly desirable in terms of promoting wellbeing (Calkins, M, Szmerekovsky, J, Biddle, I, 2007). So while a building might still incorporate a “memory trail” such as described by Martin Habell, or a garden might still contain secure “wandering paths”, sensing technology can enable these routes to be securely extended, without intrusion on normal lifestyle and privacy. This might also enable the design of such elements moves closer to the “norm”, so that a garden is a source of enjoyment for visitors and residents alike, rather than the immediately-identifiable, if well-intentioned “institutional garden”. Good design allows for more than one solution to any given problem; sensing technologies can be used to free up design potential in this scenario, and in others where creative input has often been stifled by concerns about safety of use.

A person who lives in a supported setting often lives there because of some incapacity resulting from impairment, age-related or other. If it has been acknowledged in the first instance that the person requires full-time care and monitoring, sensing can enable that monitoring to be more secure, and at the same time less personally intrusive. Thus it is *not* appropriate to monitor physical location within the confines of a residential setting, *unless* a person cannot be otherwise located. It may, however, be appropriate to monitor movement patterns or other bio-signals, and alert if they indicate, or preferably when they predict adverse events, for example, an unacceptable level of stress, or an impending fall, which is

usually preceded by identifiable changes in gait (Scanail, 2011). The answer, as with many other similar issues, “some of the data, not all of the data”. Decisions regarding what data is made available to a third party, or what events should trigger an alert, can, and should, be managed by context. While sensing is continuous, data is relayed from an individual sensor to the system only when a significant event occurs, e.g. in relation to identified threshold values being exceeded, or when patterns of activity are detected, rather than constantly bombarding the system with largely irrelevant data. Intelligence will need be distributed throughout such a responsive system, for example, sensors will require some level of local processing/ decision-making in order to filter useful information, and reduce the amount of information which needs to be processed in order to generate a response by way of actuation (Baumgarten, M, Mulvenna, M, 2011).

It is critical to note that, in a responsive environment model, locally-sensed data need not necessarily be transmitted to the web, which seems to be regarded as the *sine qua non* of every new sensing application, including bio-sensing applications in healthcare. Commercial sensing applications aimed at elderly people place much emphasis on remote monitoring systems, where physically remote carers use mobile technologies to access information and receive alerts. While web-enabled monitoring applications may be appropriate for many situations, there is an equally strong case for embedment and localised responsivity, which supplements, rather than aspires to substitute the existing relationship between the carer and the resident/patient, and assists in maintaining independent functioning. Moreover, there is a case to be made in this particular physical context, (that of the personal life-space), that all data should not automatically be transmitted to a remote monitoring station. It might be sent to a local monitoring station, but only selectively, on an as-needed basis. The closing of the feedback loop between user and environment might also serve to allay fears about protection of personal data. Invariably, there will be requirement to make value judgments about issues of privacy, versus those of resident wellbeing, even where that is interpreted as far more than basic physical safety.

In any such situation, as Malcolm McCullough puts it *“activity must be managed by context because of volume of possibilities”* (McCullough, 2004): The design of the constituent system parts, (software, hardware, interfaces, sensors), for any responsive space, where architecture becomes the interface, will be dictated by the nature of the expected (and sometimes unexpected) interactions between user and environment, which are to be mediated through the system as a whole. This becomes rapidly evident even in scenarios for a single-user responsive space, for once the room has been equipped with sufficient sensors and a system capable of usefully interpreting continuous sensor data, multiple other possibilities for use immediately present themselves, and may ultimately prove to be limited only by the imagination of the designers involved. The same necessity for management by context is seen to apply at other scales, for example, at the scale of the entire site, as described in the earlier scenario involving GPS sensing, and in the same manner, at the scale of detailed design.

There are very many situations where the capacity of an individual to communicate information about her own status is impaired; that very impairment is often contributes to the person’s requirement for care. As well as the possibility of anticipating such events through interpreted bio-sensing, an affective responsive system might also be used to communicate information on changes in user affect or other status environmentally, for example by using sensed data to actuate changes in the visual environment, rather than by simply raising an alarm. A further potential consequence of the externalisation of affective status might be to raise an individual’s own awareness of such changes. Some research has been proposed for children with ASD on that basis. (Picard, 2009) For these subjects, outbursts of anger are preceded by a significant increase in heart-rate, though there is no apparent change in facial expression. Altering the person to their own incipient emotional state might be used in that scenario to learn to manage such outbursts. For a person with dementia, it is suggested that some management of stress might be through intervention in the room environment, in addition to alerting a carer in anticipation of a “catastrophic event”. Environmental responsivity thus raises further possibilities of therapeutic intervention at the level of the built

environment. While multisensory rooms are a commonplace in day and residential care, the possibility begins to exist of a personal room, or any space, becoming capable of adaptation as required, for therapeutic purposes. In a world of rapidly-evolving digital technologies, where personal touch-screen appliances are already permeating the mainstream at primary-school level, the introduction of larger-scale displays for use by instructors is contingent only on the cost of such technologies, which is still bordering on prohibitive for widespread use. With advent of large-scale digital screens in day-care contexts comes the possibility of multiple uses, including for visual or multimedia therapy.

Taking the likely increase, or even predominance of people with dementia in residential care into consideration suggests a more efficient and user-centred approach to providing and designing for residential care provision. If a more progressive model is adopted, the careful use of monitoring technologies has the potential to provide security with less actual physical restriction. The use of wireless sensor technologies in internal environments offers further potential for unobtrusive monitoring which maximises privacy and independence, as well as the possibility of elimination of standard environmental controls (switches, etc.) allowing elderly people in general, and people with dementia as a subset, greater use of their environment, and lowered stress from the frustration due to lost ability to interpret and use controls, or to successfully communicate even basic needs. One of the hypotheses presented in “Everyware: The Dawning Age of Ubiquitous Computing” (Greenfield, 2006) is that “Everyware is strongly implied by the needs of an aging population in the developed world”, at least partly on the basis that continued autonomous living as we age is very appealing, even where it is “underwritten by an unprecedented deployment of informatics in the home”, to the extent that the adoption of pervasive computing may be an absolute necessity if we are to deal effectively and appropriately with impending demographic change. Greenfield also acknowledges that solutions developed specifically for elderly users may often have application for other user groups. New residential models should therefore take into account making provision for future technology; at the same

time, as technologies tend towards miniaturisation and wireless networking, this becomes less and less disruptive of existing building fabric, and therefore maximises the potential for retrofit.

Because of the nature of the dementia and its inexorable demographic progress, a considerable amount of current argument for ageing-in-place seem to revolve around the cost to the state of providing residential care places for a rapidly-expanding population of older people with dementia, and the deferral of a move to care for as long as possible on that basis. The prime consideration should, of course, be the question of what constitutes an optimal standard of care and quality-of-life for the person, and in giving elderly people a real choice as to how they live out their years. A change towards psychosocially-supportive care models is insufficient without a matching change in the architecture of care settings. Responsive architecture, underpinned by sensor-based pervasive computing on sensing, can afford less intrusion, more privacy and self-sufficiency, more personal choice, freedom of movement, and enhanced opportunities for “design as therapy” (Willatt, 2011).

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Chapter 5:

MyRoom I: A user-centred model of affective responsive architecture

- **A roadmap for affective responsive architecture**
- **Facilitating congruence in an elderly care setting through design of built environment**
- **Detailed recommendations for application and interaction design**
- **Key characteristics of an adaptive salutogenic room**

“You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete”

-Buckminster Fuller

A ROADMAP FOR AFFECTIVE RESPONSIVE ARCHITECTURE

The original MyRoom concept (Dalton, C., Harrison, J. D., 2010) has continued to inform the development of a more detailed description of a context-specific scenario for affective responsive architecture, in itself a novel concept (Dalton, C., Harrison, J. D., 2012). The thesis suggests that congruence in the architectural environment of care can be supported by the incorporation of real-time sensing and actuation, where affect becomes a consideration in the management of environmental response, thus creating a feedback loop which promotes salutogenesis (Dalton, C., Harrison, J. D., 2011). The promotion of wellbeing is the prime motivator for the concept (Dalton, C., McCartney, K., 2011).

As the literature review progresses, repeated comparison of the original concept with trans-disciplinary research findings reconfirms its validity as an approach. At the same time, the design problem, that is, of “what to do” with wireless sensor networks

in the built environment for elderly people, evolves in tandem with the proposed solution. Each successive iteration arising out of the review raises further queries, which are answered by a re-examination and extension of the original design concept, which results in an increase in complexity, while the core idea remains intact.

First iteration: Environment and Wellbeing

The initial concept refers only to psychosocial fit, and the idea that real-time environmental response might be harnessed in order to maximise congruence and promote individual wellbeing. Following the first section of the literature review, on environment and wellbeing, the concept is extended to take into account the requirement for functional congruence as a complement to psychosocial congruence. Wellbeing and salutogenesis in the built environment are governed by two core concepts: those of congruence and coherence. Congruence, or person-environment fit may be broken down into functional and psychosocial fit; in the built environment these are frequently addressed by the same design interventions. Salutogenesis is supported by “good design” of the built environment, which maximises not only functional but psychosocial fit. This is the theory behind statements to the effect that “good design enables, while bad design disables”. This applies equally in the context of design of environments for elderly people, including a growing subset of elderly people with dementia, affording the architect or designer a practical perspective on the problem by treating dementia as a disability, which may then be addressed through the medium of design.

Second iteration: Design, technology, person/environment interaction

The technologies survey uncovers shared theoretical concepts between design and ICT, including those of machine beauty, minimalism, and elegance in design. Minimalism in ICT (Obendorf, 2009) and thus in interaction design extends to include the notion of the Disappearing Computer (University of Strathclyde, 2000) (Streitz,

Norbert; Kameas, Achilles; Mavrommati, Irene (Eds.), 2007). The resulting querying of the MyRoom concept is answered by proposing to subsume the technologies into the architectural context. The familiar physical context becomes the system interface, and actuation/response is largely automatic, and predicated on real-time sensing and actuation. The proposal thus begins to address issues arising from designing for a user with changing abilities, and cognitive impairment. It is implicit that ubiquitous or pervasive computing requires distributed system intelligence. The idea of ongoing sensing of affect or emotion (specifically of stress) is an intrinsic aspect of the proposal from the outset; this implies that affective computing is also implicit in the concept, using sensing of bio-signals as a measure of affect. However, this iteration also results in the conclusion that data from bio-sensing must be contextualised in order to correctly infer affect. Contextualised sensing of the person, including sensing of affect, potentially presents a complete solution to designing responsive environments which cater for both functional and psychosocial fit. Machine learning, which informs intelligent system decision-making on which appropriate environmental response is predicated, is also therefore identified as a necessary prerequisite for such an environment. The proposed system, which can be largely described in terms of theoretical approaches as being based on an emergent paradigm, is predicated on use of cognitive sensor networks, which can *“perceive, learn, reason and act”*. (Henderson, 2007) Such cognitive networks emulate the manner in which cognition evolves in animal species, humans included, and are self-organising. The MyRoom model also complies with Henderson’s goals of becoming *“more cognitive”* by *“learning (models) from its own observations, and validating models during operation by comparing model predictions to sensed data”*. Of interest is that the thesis proposal has itself emerged iteratively as a *design* proposal, constructed largely from first principles.

From a synthesis of theory and technology, and in particular from the fusing of the existing concepts of responsive architecture and affective computing, emerges an entirely new paradigm for responsive architecture, that of real-time affective response. Architecture is reframed as interaction design, which responds to specific

consideration of person, context, and activity. Functionalism becomes redefined, of necessity, as usability.

Third iteration: Architecture as interaction design

The treatment of the proposal as an exercise in interaction design requires a close examination of both user and context. In the case of the former, the significance of stress in dementia becomes apparent from the review, and more specifically, a decreasing tolerance on the part of the person for environmental press. Therefore, an ideal environment for a person with dementia should be adaptable in order to compensate for loss of cognitive function, and increasing susceptibility to stress of environmental origin, so that the room environment becomes prosthetic or compensatory. The concept of an environment endowed with the possibility of continuous and ongoing adaptation also answers this query. Adaptation can be used to compensate, through practical interventions, for loss of functional congruence, but also to integrate responsive therapeutic features into the built environment to address issues of psychosocial fit. Furthermore, real-time adaptation can actively respond to changes in user status, including declining ability to interpret and interact with the environment.

An examination of context, in both the architectural and social sense, reveals an urgent need for consideration of how and where a growing population of elderly people with dementia will live out their lives, and a critical need for new architectural approaches. A degree of international consensus as to preferred models of care begins to emerge, from a survey of both research and built projects, any one of which might provide a suitable physical template for the integration of sensor-enabled environmental responsiveness. The importance of allowing sufficient space allocation to house a range of activities, in support of congruence, and to allow for personalisation, is identified as critical. These newer models challenge what has been to date a predominantly institutional view of the user, aspiring to replace this with a person-centred model. Again, the notion of personalisable environmental

adaptation, based on sensing of the person, ties in with both person-centred and inclusive design approaches.

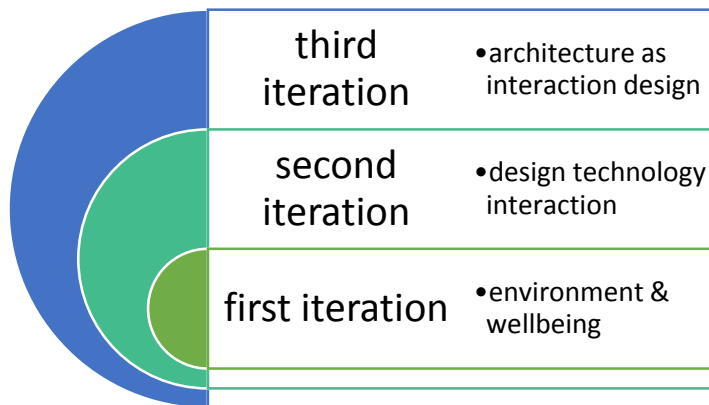


Fig. 5.1

Creative Synthesis: MyRoom

The concluding chapters represent a detailed synthesis of what has been learned from the iterations of the original concept at various stages of the interdisciplinary literature review, and effectively constitute a description of a particular scenario of responsive architecture actuated by contextualised sensing of affect. The context is the personal life-space of an elderly user who may already have, or go on to develop dementia, in addition to other conditions associated with ageing.

Issues of personalisation, and of adaptability over time are critical. These are examined firstly in terms of the physical characteristics of the space or setting, and then re-examined in terms of how environmental fit can be enhanced by the integration of sensing technologies to make responsive architecture, which both enables response to ongoing change, and delivers that response in a personalised fashion. Sensing of and response to affect are key components in designing for psychosocial as well as functional fit, to provide a complete design template. Principles for design interventions are extrapolated from the research of Judith Heerwagen on environment and wellbeing (Heerwagen, J., et al, 1995), with more detailed recommendations based largely on Corcoran and Gitlin's work (Corcoran,

M., Gitlin, L. N., 1991). The final chapter describes in some detail two specific and complementary proposals for responsive and therapeutic adaptation of the visual environment. The idea of architecture as the Open Work, which is referred to in the early stages of the thesis, becomes fully possible through the embedment of sensing and response, so that the user is continually engaged in the creation of response, and the ongoing modification of the architectural environment. Thus at each stage of iteration, the problem, i.e. the research question, evolves alongside the proposed design solution, which progressively increases in complexity. At the same time, the final proposal suggests that the eventual real-world solution, in the shape of a responsive salutogenic environment, can be designed so as to itself evolve in tandem with an evolving problem, in this case, that of declining person/environment fit arising from progressive disability due to dementia. Real-time response not only allows issues to be addressed as they arise, but also effectively allows the environment to evolve with the person.

In summary, dementia is a progressive, and to date, incurable disease associated with ageing. Its impact on the neurological mechanisms of memory leads to profound, and ultimately comprehensive impairment of function, including the performance of sequential tasks, executive memory, reasoning, linguistic ability, and ability to interpret the environment. The last is experienced in symptoms such as loss of visual and depth perception, motor control and coordination and balance. Impairments are sometimes exhibited through “Disturbed” Behaviours, such as repetitiveness, wandering, combativeness and confusion, many of which now regarded as secondary symptoms arising from environmental stressors, and as expressions of unmet needs. The capacity of environment to influence functioning of elderly people is well-researched. For a person with dementia, many mundane tasks are rendered difficult by cognitive impairment; the built environment itself may further exacerbate this effect, if not carefully considered. Distorted perception of sequence of events can lead to disorientation and confusion. A person with dementia may feel shame or anger, being aware of their inadequacies; many may worry about the future, may feel confused and vulnerable and, perhaps most

significantly, have trouble communicating their needs or feelings. Ultimately there may be fragmentation of one's very self. Current care models, as described by Gadow (Gadow, 1988), aim to prevent the loss of the person to the disease; in other words, they aspire to being therapeutic. Similar concerns, with an emphasis on recognizing the humanity and individuality of elderly people with dementia, inform John Ziesel's approach set out in *I'm Still Here* (Ziesel, 2010). Design of care settings for elderly people must therefore inevitably address the issue of designing for the specific and individual needs of the person with cognitive impairment, and with the reality of progressive decline, culminating in palliative care. The particular challenges of the design brief for an environment for such a user are not only those presented by the range and degree of impairments, but also by the issue of constant change, in the form of progressive decline. For example, in the case of Lewy Body dementia, the person may alternate between being relatively well and severely affected. Functional fit may be affected not only by loss of physical function on the part of the individual, but also by loss of cognitive function governing the ability to use controls to modify one's immediate environment, and fundamentally by loss of ability to interpret information about the environment. For the person with dementia, ordinary events and actions become increasingly stressful, as the person loses the cognitive capacity either to clearly interpret what is taking place in their environment, or to act on the information they receive. This impacts negatively on how (s)he interacts with and functions within that environment. Small tasks can therefore take on monumental significance. It is not only a case of losing the ability to remember "how" to do something, but "why", and even "when", by the stage at which the person's sense of temporality is affected.

Loss of function and independence associated with dementia-related cognitive function is often the marker for a move to residential care, so that very many older people in care have some form of dementia, and though people may live at home with dementia, many of these will eventually die, of or with dementia, in a care setting. Two-thirds of people in the US who die of dementia die in a nursing-home,

a far higher proportion than for other terminal illnesses (Alzheimer's Association, 2013). In the US, in 2008, 45-67% of elderly people in assisted living and 68% of elderly people in nursing homes have some form of cognitive impairment, 47% with a diagnosis of dementia. Impairments arising from dementia are often experienced in addition to loss of physical function, including mobility, visual acuity, or hearing, resulting from the ageing process. The increasing numbers of elderly people as a proportion of overall population, coupled with an increase in longevity will inexorably lead to a consequent increase in incidence of dementia, and the related challenge of designing optimal environments for these users. This provides the impetus to conceive a new type of responsive architecture that supports and maximises independent functioning and quality of life for older people. Any such design model must be examined at the level of close interaction between person and life-space, a boundary from which architecture has often stepped back, or where it has made broad assumptions regarding the nature of such interaction. In part this can be explained by a desire on the part of the designer to maximise flexibility of use. However, in the case of the personal life-space of an impaired user, no such casual assumptions about ease-of-use can be made, such as might be applied to the general population, if indeed such a thing exists. It has latterly become possible, through developments in ICT, to imagine a life-space which can move beyond the constraints imposed through being fixed, in terms of how it is constituted and used, to a concept of an environment that is tailor-made, and constantly remade in response to the evolving needs of its occupier, where the detail of person-environment interaction can be intimately mediated by intelligent embedded systems in a manner hitherto not possible, or even unimaginable. Both personally, and as a designer, the author shies away from the notion that such adaptability should invariably involve spatial kinetics, in the form of spaces reconfigurable at short notice: this approach seems as likely to be startling and unsettling as it is to improve functional performance, and seems very much at odds with notions of placemaking. In the context of residential accommodation for a person with dementia, it would seem profoundly inappropriate. Furthermore, such concepts often seem predicated on issues of shortage of available space.

Previous chapters have reviewed the physical and cognitive changes associated with ageing and specifically dementia, in order to elicit a comprehensive picture of the potential end-user in a residential care setting, and the very specific set of functional and psychosocial requirements which should ideally be addressed in environmental design for this person. It is acknowledged that the user-group of persons with dementia is “difficult” and challenging to design for, particularly as design for changing, deteriorating abilities needs to be taken into account. This aspect is at odds with how architects and designers characteristically view their designs, which often is as pristine and unchanged, from the moment they are handed over to a client. However, buildings do not remain static and unaltered after the architect ceases to be involved. This is the architect’s downfall, the “bête noir”: what will they do to my building? A building is much more than a static spatial composition, to be admired without touching in the manner of sculpture. There is a multiplicity of actual and potential interactions between any user and her environment. How well a setting accommodates these is a good measure of its success as a piece of design. The role of aesthetics in design is inextricably tied into to how architecture functions on not only the psychological/emotional level, but on how well it performs practically, where “good design” becomes synonymous with usability. The task here is that of constructing a framework for facilitating managed and considered adaptation of the built environment for this particular user and context. That challenge, in the presence of sensing technologies, becomes an opportunity for a creative approach to contextualized interaction design at the scale of the built environment, which enables individualisation and adaptation through responsivity. It must always be borne in mind that, where interaction design is concerned, at the interface between the user and an embedded system, context is everything. Who is the user? Where does the interaction take place? What are the user’s needs, both general and task-specific? What are the desired outcomes, design and other? Because of the defining characteristics and particular vulnerability of an elderly user-group, a very broad and complex range of issues must be explored in any such model. Arising from this, the issues identified and solutions posited may have wider application in other contexts, for other users who

share some of the characteristics of the elderly person with dementia. As such, the principles of Inclusive Design are also applied.

While a long-term care environment should meet minimum criteria in terms of physical configuration, as described later in this chapter, congruence can undoubtedly be enhanced by responsivity and evolving adaptation. In the MyRoom model, environmental characteristics such as lighting, temperature, colour and images are altered to provide a constantly variable environment best suited to an individual's needs at a given time. It is in care settings where this approach stands to deliver the greatest benefits. The increasing numbers of elderly people, and the inevitable increase in incidence of dementia provides an impetus to conceive a new type of responsive architecture that supports and maximises independent functioning and quality of life for older people. There is a very strong argument, where a user experiences cognitive and/or physical impairment, and especially where that is progressive, for provision of what is essentially a hyperfunctional personal life space, facilitated by a responsive wireless sensing system. In the model described here, the individual's room, which in the context of long-term residential care functions also as their "personal life-space", in addition to being designed to higher spatial standards in order to maximise congruence, is for the same reason enhanced by integration of a responsive, intelligent system of sensors and actuators which control multiple aspects of the environment, as part of a building management system. The incorporation of affective computing into the model is assumed as a prerequisite where responsivity is intended to fully support psychosocial congruence. Evolving environmental response suggests a means to address issues such as cognitive decline, communication of need, and gauging usability.

Bearing in mind the needs and characteristics of the user, in the physical context of the personal life space, this chapter explores a design framework for a responsive salutogenic room environment for an elderly person in a residential setting, and

specifically, for embedded environmental interaction enabled by sensing, and sensor-based actuation. It includes a detailed description of the individual's room or life-space in a long-term care setting, firstly from the point of view of how it is physically constituted, in terms of spatial characteristics, ergonomics and functionality, and then from the perspective of how pervasive or ubiquitous computing might be deployed so as to enhance and supplement the salutogenic characteristics provided by the designed environment. The room environment is always conceived of as an integrated whole, where the responsive system becomes an intrinsic component of the many potential interactions between the room and its occupant, and increases both the number and individual potential of such interactions. The focus at all times is the individual user, and the optimisation of that user's wellbeing. The characteristics described have application beyond the specific context of provision of residential care, and are relevant also to the individual life-space in a domestic setting, as well as to workspaces, which have provided the setting for much previous research into the effects of stress on human performance.

In healthcare design, a consideration of the evolving temporal relationship between stress and illness, and the possibility of moderation of stress through environmental congruence, has a critical role in establishing parameters for supportive designed environments. Those same considerations extend to the design parameters for environments whose supportive capacity is enhanced through integration of embedded sensor networks. When the end-user of the design is a person with dementia, or an elderly person at risk of developing dementia, those concerns become greatly magnified, because of the specific nature of the disease, the identification of stress a causal factor, as well as a recognised trigger, and the inevitable and progressive diminution of tolerance for environmental stress in the individual as the disease progresses. On that basis, particular attention should be given, in the design of residential care environments for elderly people, to mitigating stress originating in the physical environment by means of design, using a two-fold approach.

Firstly, the design must consciously aim to reduce unnecessary cognitive stress for a user who is likely to be, or become, as they age, physically and/or cognitively-impaired. This may be achieved by designing for both functional and psychosocial fit. Secondly, the design should attempt, where possible, to actively relieve stress of environmental origin, which will inevitably arise in the case of a person with dementia. The latter approach implies active promotion of wellbeing, through a variety of design approaches, extending to enhancement of supportive environmental characteristics through use of embedded wireless systems, which mediate person-environment interaction on an ongoing basis. In this proposal, sensor networks which facilitate continuous real-time interaction between user and environment will use affect as a parameter for management of system actuation, in addition to functional considerations. The same data might also be used to observe how any change in the environment/context, including those actuated by user affect, in turn impacts on user wellbeing. In this manner, the same systems which facilitate continuous and psychosocially-supportive management of a personal life-space, are also simultaneously capable, through continuous feedback, of being used as tool to test design interventions, and to do so iteratively. This is very much in the nature of interaction design, but here, architecture becomes the interface, and each room environment a “living laboratory” for its individual owner. A sensor that is acceptable in lab-based research is unlikely to be so in an everyday real-life scenario, and may be extremely unwieldy and intrusive. In the case of elderly people with mid-stage dementia there is a significant likelihood of removal of any alien object, such as an identifiable wearable sensor. This situation requires a radical rethink of how sensors and sensor networks are physically constituted. Design and development of sensors and sensing methods should ideally be informed by the specific consideration of the identity of the ultimate end-user or consumer. As such, any future research relating to the realization of a therapeutic room environment must ultimately be framed as person-centred design research. In the case of a vulnerable end-user, such as an elderly person who requires supported accommodation, much current sensing apparatus for Body Sensor Networks (BSNs) may not be practicably suitable, because of the possibility of a sensor of itself acting to increase user stress, and intrusion on activities of daily

living. In the MyRoom scenario, BSNs, if deployed, should take the form of genuine wearables, which is to say, not in the sense that many “wearables” are currently constituted. If the sensors are to be used on a continual basis in a live environment, as envisaged in this model, and most particularly if they are to be used with vulnerable subjects (which describes almost any patient in a care setting), they must, of necessity, become discreet and non-intrusive almost to the point of invisibility. The term “wearable” might therefore be redefined in this context as a non-contact sensor which can be incorporated into the user’s own clothing. Power-supply/battery size appears to be the principal barrier to reducing overall sensor size. In order to develop suitable sensors, and sensing methods, for use in responsive environmental systems an obvious research priority is miniaturisation, not only of the processor and sensor, but principally of the battery or other power-source. Research into energy harvesting is also therefore of significance, as an alternative route to the same goal. Smart textiles may offer solutions to more than one issue: for example, a thin, flexible textile sensor substrate would permit incorporation invisibly into the user’s own, familiar clothing. This replaces current approaches where specialised clothing is required. Available wearables, for military applications include tight-fitting neoprene vests with a chest sensor measuring several centimetres in diameter, mostly comprising a battery pack. What might be literally a lifesaver on the battlefield is not a wearable on a day-to-day basis in a domestic setting, all the more so if the intended end-user is impaired in any way. More promising research includes development of stick-on biometric sensors, and embroidered antennae. Need and potential exists for multifunctional smart textiles, which are capable of both sensing, and energy harvesting to power an integrated sensor.

An alternative, and more architectural approach, as suggested in Chapter 4, is to design the system so as to rely only on room sensor networks, (RSNs) embedded in the fabric of the built environment. This approach also acknowledges researched preferences of elderly users (Bakkes, 2011), and suggests novel sensing methods, including gait and video analysis, both of which are being actively researched

(Scanail, 2011) (McDuff, D., et al, 2013). There is a considerable body of existing and ongoing research into gait analysis, because of its importance in falls detection and prevention. Falls are major cause of hospitalization and ensuing mortality. Falls prediction is achieved through detecting predictive changes in gait, from kinematic data, and using machine learning to identify adverse events. Existing gait applications developed through research have to date been clinic-based: i.e. the elderly person attends a hospital clinic, and is assessed using wearable sensors and specialised software, by a clinician, for example, the gait analysis research carried out at the TRIL Centre. When such predictive monitoring is enabled to move, unobtrusively, out into the person's own life-space, there is significant progress towards supporting ageing-in-place. A gait-analysis system may be based on sensed data from wearable accelerometers, video analysis or sensed data from a floor fitted with pressure sensors, such as the SmartFloor (Orr, R. J., Abowd, G. D., 2000), that is, via either BSNs or RSNs. Overlaid with machine-learning capacity, a system might provide a non-intrusive early-warning system. A further advantage of environmentally-embedded sensing is that elderly people may be uncomfortable wearing a visible sensor, especially in social situations, where other people are present (Doyle, J., Bailey, C., Dromey, B., 2009). However, this last-mentioned research does not include sensor design as a variable. The perceived intrusiveness of a wearable sensor must, of necessity, be closely associated with its physical reality. Even over the timescale of the thesis research, significant progress has been made in both sensor design and sensing methods. The significance and usefulness of the types of information that can be gleaned from on-body sensors in creating a rounded model of affect on a continuous basis must be considered. Sensors will require some level of local processing/decision-making, so that data is relayed from an individual sensor to the system when a significant event occurs, e.g. in relation to identified threshold values being exceeded, or when patterns of activity are detected, rather than constantly bombarding the system with largely superfluous data.

In consideration of design of any sensor-enabled environment, including where it is endowed with responsivity, it would seem obvious that related design research, and particularly research regarding the psychological effects of the built environment, should ideally be carried out longitudinally, and situated in a live care environment, in order to produce reliable results which have practical application for designers. The technologies required to support responsive environments therefore also have application in this context. For longitudinal research on vulnerable subjects, in live environments, current sensing methods are often ethically unacceptable, which is a reflection of their impracticality for long-term continuous real-time sensing. There is a real and undesirable prospect of a wearable sensor in itself becoming a source of stress. In an environment designed to support wellbeing, this is not a viable approach. EEG sensing, though it might provide invaluable data regarding neurological and psychological reactions to environment, is one such example. The traditional apparatus, with scalp electrodes, is completely unsuitable for use in live settings when, even in the limited context of a laboratory setting, it constitutes a significant stressor, this being greatly exacerbated in the case of a person who has cognitive impairment. To a designer with any interest in usability, or person-centred design, it would be unthinkable to use such an intrusive and restrictive device on end-users. From a technical point of view, EEG data gathered in a live situation, though hugely informative in relation to affective state, is likely to be corrupted by movement “artefacts”: that is, data from signals originating from the parts of the brain involved in movement. Newer, portable EEG headsets have already been used experimentally to gauge subject reaction to external environments (Aspinall, P., et al, 2013), and some also permit real-time transmission of sensed data. EEG sensing is also being utilised in other trans-disciplinary research, to test user reaction to virtual environments. Such research has the potential provide detailed insights into how architecture and the built environment affects the brain, and thus its effect on wellbeing. In the proposed scenario, sensing technologies might be used to gauge the success of design interventions, whether they are made through purely architectural intervention, or through architecturally-embedded interaction design.

Given the pace of development in sensing technologies, one can accept that it is only a matter of time before BSNs have evolved to the point either where wearables are miniaturised, to the point that they become completely non-intrusive, or RSNs becomes sensitive enough to allow reliable and useful off-body sensing of bio-signals. It is self-evident, given the significance of person and context in interaction design, that design of sensors for use in specific contexts must be guided by the characteristics of both user and context, as well as by the set of interactions which are to be supported. Much of the impetus for research into remote or off-body sensing of bio-signals has been provided by biometrics research following on the 9/11 disaster. It is now possible to use radar to detect heartbeat through a wall (Shirodkar, S., et al, 2011). If sufficient data regarding heartbeat can be acquired remotely, it might then be processed, for example, to track affect. Many of the technologies required to realise a responsive architecture which responds to affect already exist, if sometimes in rudimentary form, and in other areas of use. The precise design of the sensor network will always be influenced by the trinity of user, context, and desired interaction. A tendency towards miniaturisation and environmental embedment, while arguably of most benefit in environments for users with cognitive or physical impairments, is likely to facilitate a multiplicity of design approaches in many other architectural contexts, for a wide variety of users. As such it embraces an Inclusive Design approach.

FACILITATING CONGRUENCE IN AN ELDERLY CARE SETTING THROUGH DESIGN OF BUILT ENVIRONMENT

This section first sets out the general design characteristics of a personal life-space which consciously aims to address, through design, issues of both functional and psychosocial congruence. It continues by proposing more detailed recommendations in relation to interventions/applications enabled by digital technologies and sensor-based actuation. In the built environment, provision for both psychosocial and functional aspects is not only *not* mutually exclusive, but can, through thoughtful and imaginative design, be made coincident. This approach is extended to apply to environments where the supportive, or salutogenic capacity of architecture is enhanced through the integration of architecturally-embedded pervasive computing. The general recommendations are in part derived from Judith Heerwagen's analysis of environmental factors (Heerwagen, J., et al, 1995), supportive of wellbeing needs. A summary table is included at Fig. 5.2. The more detailed proposals which follow, in relation to sensor-actuated and digital design interventions, are derived largely from Corcoran and Gitlin's principles for interventions in the home environments of elderly people with dementia (Corcoran, M., Gitlin, L. N., 1991). While the principles were developed with a family home environment in mind, they can also be readily and appropriately applied to the assumed context for this room model, that is, a clustered housing care setting, or one which involves group living in self-contained private units. Contemporary theoretical and built models include both approaches, as seen in the preceding chapter.

Experience/Need	Environmental features and attributes
Connection to nature and natural processes	Daylight; views of outdoor natural spaces; views of the sky and weather; water features; gardens; interior plantings; outdoor plazas or interior atria with daylight and vegetation; natural materials and décor.
Opportunity for regular exercise	Open interior stairways; attractive outdoor walking paths; in-house exercise facilities; skip-floor elevators to encourage stair climbing.
Sensory change and variability	Daylight; window views to the outdoors; materials selected with sensory experience in mind (touch, visual change, color, pleasant sounds and odors); spatial variability; change in lighting levels and use of highlights; moderate levels of visual complexity
Behavioral choice and control	Personal control of ambient conditions (light, ventilation, temperature, noise); ability to modify and adapt environments to suit personal needs and preferences; multiple behavior settings to support different activities; technology to support mobility; ability to move easily between solitude and social engagement and spaces to support both
Social support & sense of community	Multiplicity of meeting spaces, use of artifacts and symbols of culture and group identity; gathering “magnets” such as food; centrally located meeting and greeting spaces; signals of caring for the environment (maintenance, gardens, personalization, craftsmanship)
Privacy when desired	Enclosure; screening materials; ability to maintain desired distances from others; public spaces for anonymity.

Fig. 5.2 Features and Attributes of Buildings linked to Well Being Needs and Experiences

(Heerwagen, 2006)

GENERAL DESIGN PRINCIPLES

(i) Adequate space provision

The most fundamental requirement, in architectural terms, for supporting both functional and psychosocial congruence for the elderly person in care, (including the person with dementia), is that of sufficient space allocation to allow the person’s own room to perform as a multifunctional personal life-space. It is taken

that the context for this space, or room, is a group living setting, whether that be apartment-based, or a household model, based on the identified benefits of such settings. This supports *behavioural choice and control* in the most fundamental manner. Increased space provision immediately begins to address a greater number of functional needs: at a very basic level, it allows a user greater space to manoeuvre, including space for mobility aids, wheelchairs, and also for care assistants to work. Facilitating independent functioning can empower a user, and may thus relieve carers of some of their burden, in the same way that promoting independence through inclusive design can prolong a person's ability to live at home. Making sufficient space available also better supports engagement in an increased range of activities, beyond the very basic functions of sleeping and personal hygiene. A basic list of other activities to be supported might include the following: reading/looking at pictures, watching TV or video, listening to music, carrying out personalised occupational therapy, receiving visitors, making tea. Such activities in themselves are supportive of enhanced psychosocial congruence, through facilitating self-actualisation. Space provision also can support needs for privacy and private socialisation, and, very importantly, for being securely alone, to relax or simply "daydream" (Corcoran, M., Gitlin, L. N., 1991). The integration of real-time monitoring of wellbeing into the room environment can serve to reinforce both security and privacy. All of the measures described here, including for technological intervention, are largely passive.

It is simply not feasible to provide for all these needs while limited by the areas defined by many contemporary care standards, typically ranging, in Ireland and the UK, from 12 m² to 15m² for a single bedroom. While the Onni residential care building (see Chapter 4) provides residents with bed-sit type accommodation, as well as communal spaces, many models which are promoted as being progressive, provide space in the resident's own room which realistically only allows for sleeping and grooming. It must be remembered that in a residential care setting, a resident's own room usually provides the only available *personal* space for relaxation, privacy and self-actualization. While more evolved US care models, such as the

GreenHouse® provide single or double bedrooms in small-scale units, space provision within bedrooms still ensures that multi-functional use is effectively curtailed. If the true intention is to design with a focus on the individual user, such an approach cannot presume to meet needs for psychosocial congruence, as described, and is therefore ripe for re-assessment. Though “household” type models are based on the scale and detail of domestic buildings, it should be borne in mind that the “household” is artificial: residents may have little or no choice about those with whom they cohabit. Where only shared spaces (e.g. dining and living-rooms) are available for socialisation, they do not provide the same levels of privacy as similar spaces in one’s own home: it is not always possible to predict or control who else may be sharing that space. Visitors’ rooms are often a sort of “no-man’s land”; they can be impersonal, and not conducive to informal socialisation. Ability to socialise is influenced by availability of designed as well as unintended places to meet. (Archea, 1977) Environment governs not only opportunities for socialisation but also types of socialisation facilitated: the level of privacy in a physical setting affects degree of disclosure in conversation, and the level of intimacy achievable. Lack of user choice as to the types of socialisation in which they are permitted to engage actually militates against psychosocial congruence and wellbeing. The resident’s own room therefore takes on additional significance as a potential location for more intimate socialisation, for example with family, or for meeting carers or clinicians in a familiar and reassuring environment. By the same token, it may also afford space for privacy, relaxation and psychological restoration. If suitable space for such activities is not available, this will inevitably impact negatively on well-being. The manner in which a building is designed, and how space is allocated, thus contribute to or detract from behavioural choice and control. Lack of control, environmental deprivation and inability to regulate personal comfort all contribute to stress (Heerwagen, J., et al, 1995). Ultimately many of these design outcomes remain within the control of the service-provider, as the author of the project brief, rather than the architect or designer. Solely on the basis of space limitations imposed by design briefs, the design of many contemporary care settings in Ireland is insufficient to support wellbeing needs, even where single bedrooms are provided, as these are almost invariably

undersized, in functional terms, even when designed in keeping with current standards. Lack of space will inevitably result in activities being supported only in a limited or predetermined form, no matter how otherwise well-designed the context. The need for increased personal life-space is recognised in research-based architectural models, including those of Better Care Homes, and that of Jenny Willatt's 'Therapy by Design', either of which would serve as a valid physical template for MyRoom.

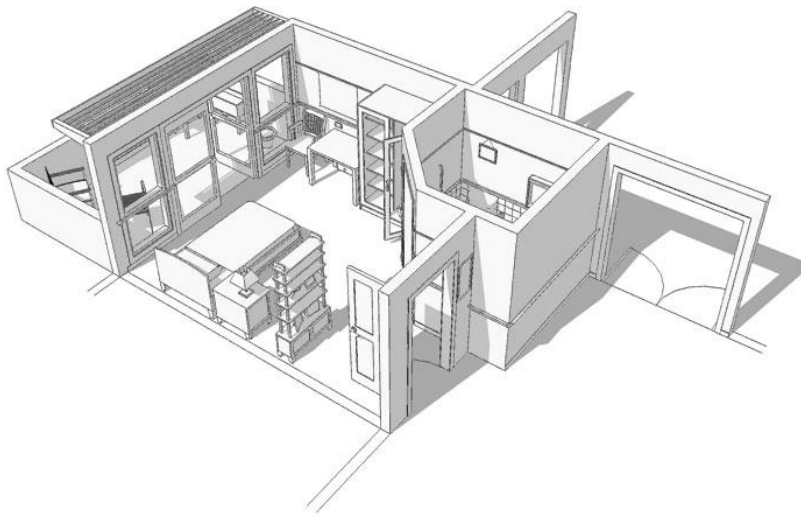


Fig. 5.3 Better Care Homes-individual room layout

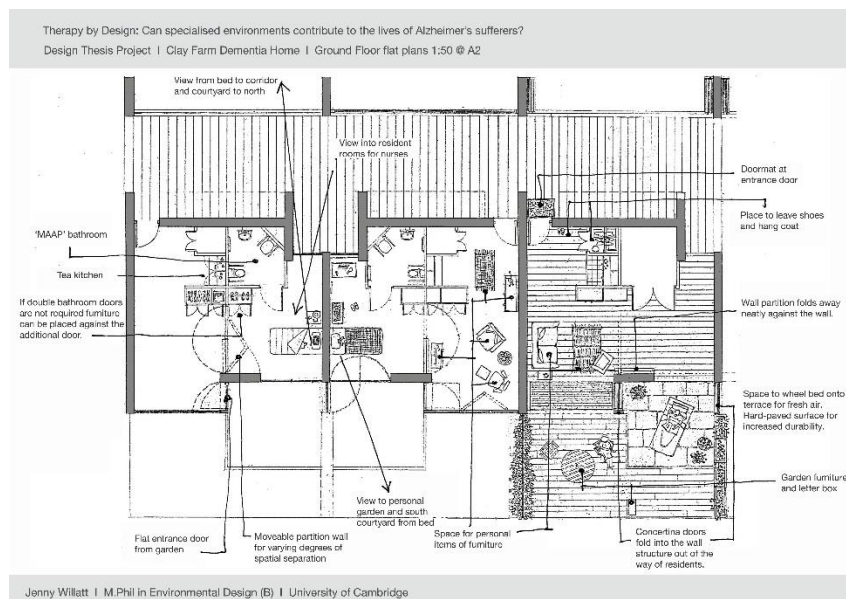


Fig. 5.4 Jenny Willatt, Therapy by design: Layout of resident flat

(ii) Design of the architectural interface with external environment: windows, openings, intermediate spaces, external spaces.

In the design of a resident's room, the most obvious means of making a connection to the external natural environment, and thus to nature and natural processes, is through carefully considered design of the external envelope, so as to optimise views and natural light. Windowsill heights, relationships to external spaces, resulting available views, position and type of external planting, and internal room layout all require detailed consideration in order to maximise potential benefits. A thorough consideration of the characteristics of the room's occupant is of equal importance in ensuring the success of any design intervention. An older person in residential care or supported housing may have restricted mobility, or be confined through illness or disability to bed, or to a seated position for long periods. That restriction may be temporary or chronic, and may progressively worsen. The impact of seasonality needs to be taken into account, in temperate latitudes at least, as it may impact negatively, as much as positively, on external views available from any single room. While views of summer sunlight and autumn colour may be pleasing and uplifting, dead winter vegetation and grey or rainy skies are not! Careful consideration of provision of external views also support needs for *sensory change and variability*. While designers often recognise the merit of providing views to external landscape, and aim to incorporate it into buildings, in practice, the design intention is likely to be compromised by a number of factors, not least of which are the particular characteristics of the occupant in a long-term care setting. Any individual room will of necessity have a fixed, and usually single orientation. This affects both quantity and quality (brightness, colour) of daylight entering a specific room, which can contribute positively to sensory variability, and reinforce sense of temporality. However, it is almost impossible for each individual room to be located so as to enjoy an ideal orientation. In domestic design, in temperate latitudes, it is common to locate rooms so as to benefit from natural light at those times of day when the space is most used, e.g. living areas face south and south-west, while bedrooms face east. While communal spaces in residential care settings are often located to benefit from optimal orientation, the same priority may not be applied

to resident rooms, which may be left with less desirable orientations. Seasonality and orientation also affect connection to the natural environment and awareness of natural processes. In the preferred domestic-scale care setting, orientation will be greatly influenced by a combination of siting and priority of function: in short, if communal spaces “get” the best aspect, bedrooms may be relegated to less favourable positions. Small-scale courtyard models, which are common, while providing a secure external space, may also unavoidably restrict available orientation.

An individual resident’s room should enjoy direct and usable access to the outdoors, preferably initially to a personal covered space, giving onto shared secure external space. This recommendation is consistent with those of other research-based design models. Openable sliding doors/windows, and level thresholds facilitate independent access to the external environment, for as long as mobility allows, and allow assisted direct access thereafter. This aspect is also highlighted in Jenny Willatt’s design, where a wide sliding door allows beds to be wheeled out into a personal covered area. Physical provision for ease of external access not only permits contact with the external environment, but encourages gentle exercise, allows exposure to sunlight, can further increase awareness of seasonality, and strengthening of circadian rhythms.

The provision of direct access to outdoors from personal space is still uncommon in practice in residential care design, despite the fact that single-storey buildings are the norm in many countries (Ireland, UK, US), often for reasons of fire safety. In a multi-storey building (more common in continental Europe) a balcony or winter garden may be provided. Even so, a frail elderly user’s physical status may mitigate against independent or spontaneous use of such access, particularly during inclement weather. In residential care settings, such external access is, at present, commonly provided only from communal areas. The possibility of direct physical access to outdoors from an individual resident’s room, as described, is rarely

considered in Irish models, though it might easily be afforded where the general external space is suitably configured and secure. It seems in some respects that healthcare design has regressed: this orthopaedic hospital, built in the 1940s, has direct access from wards to the exterior.



Fig. 5.5 Kilcreen Orthopaedic Hospital, Kilkenny, Ireland

Facilitating ease of physical access to external spaces can also facilitate contact with nature. The detailed treatment of the boundary between the indoor and the outdoor will impact on the realisation of the design intention. The provision of a sheltered and protected transitional external space, which is personal to the user of the room, (e.g. patio, veranda) is likely to encourage use of outdoor space. The provision of such access also increases freedom of individual choice and supports a variety of behavioural situations. On a functional level, it is simply a matter of providing easy level access to a private outdoor space. Psychosocially, it supports a number of situations: it allows the person simply to relax, alone, in a secure personal space, while remaining outdoors, with a connection to nature, and exposure to daylight; it can also facilitate socialisation, by choice, with neighbouring residents. This area can be treated, in design terms, as an external room, acting as an extension of the personal life-space, and also as a buffer between the room and the shared, more public spaces of a garden or courtyard. Enhancing the physical connection between indoors and out has been a recurring theme in my own healthcare design work. Increased glazed area also permits increased exposure to

daylight, whose benefits are well-documented (Hobday, 2006), and fosters an increased awareness of seasonality and time of day, reinforcing temporal boundaries. Sensor technologies can enhance availability of connection to the outdoors in various ways. For example, doors might open using a gesturally-activated sensor, or automatically using a motion sensor or floor pressure sensor.

The design treatment of external spaces can enhance or detract from a building's relationship with the external environment. External space can ameliorate negative aspects of context by acting as a buffer space between buildings, when it can provide screening, or between private and public realms. The boundary between inside and out maybe treated in a manner that responds to a need to modify the impact of climate, views, daylight, etc. In a well-designed building this may result in a complex and varied relationship that enhances both the internal space and its context. But what of the person who, largely by virtue of age or impairment, is mostly confined to an environment which barely extends beyond a single room, with a single aspect, a single view, and perhaps even then, a viewpoint restricted by physical or cognitive infirmity? This person's experience of the totality of a building and its potential may fall far short of that envisaged even by a competent and well-intentioned designer.



Fig. 5.6 Dungarvan Community Hospital, Ireland (Dalton + O'Donnell Architects)

(iii) (Progressive) automation of environmental controls

Ageing is usually accompanied by loss of physical function, while dementia is inevitably characterised by progressive loss of both cognitive and physical function.

Loss of fine motor function affects ability to manipulate switches and controls. When it is combined with cognitive impairment, sufficient to prevent loss of understanding of how controls operate to alter the environment, compensatory intervention should be made. The loss of choice and autonomy is, in itself, a source of frustration for an individual. There is therefore a very strong case to be made for automation of environmental controls, such as those for lighting, heat and ventilation. The introduction of sensor-enabled response into the built environment has the potential to enhance environmental congruence both passively and actively. The most obvious benefit is by greatly reducing or eliminating the need for manually-operated environmental controls, by introducing automated response to a user's changing needs. Depending on how such systems are designed, they may extend beyond supporting functional congruence, to supporting psychosocial congruence, for example, by enabling multi-sensory cuing, or reinforcing circadian rhythms, thus extending into what is effectively a therapeutic intervention.

Practical suggestions include replacement of manual switches, requiring small motor control, with pressure pads, or alternatively with gestural interfaces activated by gross motor action (involving moving a hand rather than use of fingers), and ultimately, in response to user location and activity. Use of haptic (touch-based) interfaces can reinforce self-identity. Where generating a response requires conscious action on the part of the user, the interface should use strong visual cuing. The appropriateness of the solution depends on the ability of the occupant. The provision of gesturally-activated switching should not exclude the simultaneous provision of the capacity to operate on an automated basis when the need arises, later in the progression of dementia. It is also likely that as such technologies become commonplace in buildings in general, they will be familiar to future users of residential care. Environmental thermal sensing might be used to locally activate automated shading of windows to avoid glare, or thermal discomfort from overheating due to solar gain, in the manner of larger-scale responsive facades.

Active participation in managing personal environment may help reinforce self-

identity. However, a post-occupancy evaluation from the Maggie's Centre in Dundee (Stevenson, F., Humphris, M., 2007) suggests that users who were ill, (rather than cognitively impaired), were not concerned with personally managing their environment (in thermal and lighting terms), perhaps on the presumption that a carer would manage it on their behalf. In this sense a room management system can act as a "servant" to the occupant, and may thus leave the carer free to engage in more meaningful interaction with her. The introduction of affective sensing into the interaction may potentially provide valuable clues as to identifying specific sources of stress in a room environment: e.g. an intelligent, context-aware and affective system might learn to associate increased stress in a user with simultaneously sensed environmental changes, such as glare, or overheating, and respond accordingly. In this fashion a user's inability to recognise or communicate or a source of environmental stress might be addressed.

Automation of environmental controls, with the primary intention of maximising physical comfort for the occupant, can also thus reduce the cognitive load, and attendant stress, of having to remember and interpret multiple manual or digital controls. Automation also removes or reduces the need to rely on assistance from a carer, and the need to communicate what are very basic needs, including where it is no longer possible for the person to successfully communicate those needs. In this fashion, addressing what seems at first glance a purely functional issue can lead to desirable psychosocial outcomes, by reducing the possibility of stress arising from physical discomfort, and from an inability to communicate need. System design might include for progressive automation, so that the degree of automation responds to changes in a person's condition, where it declines either physically or cognitively. For example, controls might progress over time from provision of large-scale haptic or gestural interfaces, to complete automation based on sensing of user use patterns. In either case, a system can be designed to also provide for multisensory cuing, in order to support daily activities and circadian rhythms. This is addressed in more detail in the description of a supportive lighting system. An adaptable system, or one with alternative manual and automatic settings, might also allow for exploration through research, as to how desirable direct personal

control actually is, from a user perspective. In a personal, rather than a shared space, user perceptions of control may differ.

Management of the environment, as well as progressive and tailored adaptation of controls as described above, will be supported by a system which uses machine learning to inform decision-making. Machine-learning can be refined through coaching from carers, described as “interactive reinforcement training” (Thomaz, A. L., Hoffman, G., Breazeal, C., 2005) of the system, or “supervised learning” (Fiebrink, 2010). Feedback based on sensing of the user’s affective state might be similarly used to reinforce system learning of user preferences. This further may enable a degree of environmental management appropriate to the user’s physical and cognitive status at any given time in the progression of dementia. System training by carer intervention should aim at high-level rather than micro-management of system operation.

(iv) Provision of dynamic internal lighting system

While it is fully accepted that access to, and views of nature and the external environment are beneficial and support wellbeing, it must also be acknowledged that in these latitudes, there are many days of the year when access to the external environment is impracticable due to bad weather, even when physical access is explicitly catered for. This restriction will apply even more to an elderly person who is frail or physically incapacitated. Seasonality will thus affect both physical access and visual connection to nature. In the case of a person with restricted mobility, and particularly a bed-bound person, there is a strong case to be made for supplementing the internal environment of the room in such a fashion as to enhance sensory change and variability. Richard Neutra, in “Survival through Design” makes an argument for constantly changing interior lighting, reflecting natural and seasonal variation, in order to meet physiological need (Neutra, 1954). He also refers, especially in the absence of such an internal lighting scheme, to provision of a visual, i.e. transparent connection between inside and out, to

moderate the impact of static light and colour, the latter rather bluntly described as “physiologically speaking, unfit”. Many of his comments are extraordinarily prescient, though at the time of writing, the technologies necessary to realise what he described were lacking. That is no longer the case: LED light sources allow near-infinite colour variation, dependent only on programming of controllers, while sensing and embedded actuation make nuanced control of ongoing colour-light ambience finally feasible. The design proposal in the following chapter attempts to comprehensively address issues of colour, lighting and dynamic variation in an internal environment, approaching what Neutra describes as “a biologically perfect interior by technological means” As a species, we thrive on stimulus. We evolved living in the open, in an environment that varied not only from day-to-day, but also from minute-to minute, and second-to-second. Too many existing care settings are so depersonalised, and devoid of detail and variety, that they approach sensory deprivation of the resident, a point well made by Martin Habell in “Cruel Habitation.” (Habell, 2009) At the same time, overstimulation of the person must be avoided.

(v) Detailed consideration of the room as a user interface

Where architecture is envisaged as the interface for responsive interaction, detailed consideration must be given to the design of the interface(s), taking into account the many possibilities for interaction, and given the nature of the user as a person with progressive cognitively-impairment. The following section contains more detailed recommendations for integration of ICT and sensor-based applications into the personal life-space.

DETAILED RECOMMENDATIONS FOR APPLICATION AND INTERACTION DESIGN

The recommendations that follow are derived from Corcoran & Gitlin's principles (Corcoran, M., Gitlin, L. N., 1991). These principles are themselves based on Barris' model of environment (Barris, R. et al, 1985), where it is represented as a four-layered hierarchy, building on Lawton's theory of environmental press. (Lawton, M. P., Nahemow, L. E., 1973) (Lawton, 1982) Impaired or reduced competence renders a person more vulnerable to environmental influences, and increases the likelihood of negative behavioural adaptations, such as "disturbed behaviours" as a result of maladaptation, echoing Boyden's theories on the negative outcomes of lack of psychosocial congruence, the so-called "Gray Life", an unintentionally apposite description in this case (Boyden, 1971). The principles provide a framework for manipulation of the environment to match environmental press with user competence. "Environment" is assumed to include expectations of behaviour from the user. In the case of the person with dementia, those expectations may be too great, or may become so over time as cognitive decline progresses. The principles can readily be reframed so as to form a coherent basis for design of environmental interventions for people with dementia, including where they are enabled by ICT and sensing technologies. The overall intention is to direct designed interventions so that they assist in matching user competence with environmental press. This might alternatively be described as designing so as to enhance congruence in relation to person/environment fit, in the context of the personal life-space. Creative intervention supported by wireless sensor networks thus has the capacity to enhance the intrinsic capacity of a designed care environment to support congruence. It is critical for the designer to constantly bear in mind that reduced, and constantly deteriorating competence, in both physical and cognitive terms, renders a person with dementia increasingly vulnerable to environmental influences, with ensuing increased stress arising from diminished congruence. More specifically, it has been suggested that as stressful situations accumulate as the day progresses, a person with dementia experiences a lowered stress threshold, which can lead to an increased likelihood of a "catastrophic reaction" (Hall G, 1987): aggressive outbursts, or restlessness associated with "sundowning" (Bachman, D.,

Rabins, P., 2006). Many so-called disturbed behaviours similarly may arise from a mismatch between competence and environmental press, and might be successfully addressed by environmental manipulation, as it is unrealistic to expect adaptation on the part of the user in this scenario. In this scenario, the environment 'learns' from the user, in compensation for the user's loss of ability to learn.

The principles that follow are set out mostly in relation to the two innermost environmental layers of the Barris model, that is, *objects* and *tasks*, which are most relevant to the user's personal life-space, with some reference to the outer two layers, *social groups/organisations* and *culture*. While the latter two principles may not seem immediately relevant to design of a room environment, they are all applicable to the overall design of a complete care setting. Those in relation to objects and tasks are directly relevant to the room. However, the manner in which an environment is designed to manage both tasks and objects can impact in an outward direction on how social groups operate. For example, if there is inadequate space for intimate social interaction in the resident's room, such space(s) should be provided elsewhere in a building. If not provided elsewhere, this creates an unmet need, which may impact negatively on an individual, through limiting that individual's other social interactions. If a person needs to be alone, being forced into a social situation is very undesirable. The care culture of the client or commissioning body may dictate the parameters of the architectural design brief, and impose spatial and other limitations on the designer, which in turn, limit behavioural choice and control on the part of the user. This applies in all contexts, but traditional care settings tend to restrict available choices, both consciously and otherwise. In the context of a managed care setting, which is the assumed context in this proposal, the specific regime, or "culture" of care replaces familial culture in the Barris model. The culture of care is thus critical in terms of how the inner environmental layers are realised, and which interactions are facilitated or permitted. Another example of how the inner layers impact outwardly is the common restriction, or outright ban, on use of personal and familiar furniture and objects in a residential setting, which can be imposed in a variety of ways, not only

through regulation, but simply by allowing insufficient space in the resident's own room. In an Irish context, infection control regulation effectively prohibits use of personal furniture in nursing-homes, while in Finland, the practice is now being encouraged. The cultural model of care, (e.g. institutional vs. household) and its particular and inherent view of the individual (person vs. patient) impacts relentlessly on all the inner layers, and their interplay and possible outcomes. Ideally, the care model, which from the outset is often the progenitor of the architectural model, should allow for a sufficient degree of flexibility to maximise person/environment fit in as many situations as can reasonably be envisaged, in order to allow the resident to continue with as many aspects and occupations of their previous living-situation as can be facilitated. The strength of good design is to extract the maximum number of such possibilities from a spatial brief; at the same time the overly-restrictive nature of many such existing client briefs must be acknowledged, and some sort of balance struck going forward. The potential which lies in the integration of sensor-activated networks is to stretch those possibilities still further, while bearing mind the requirement to do so with minimal intrusiveness, except where the design intention is to make the interaction overt.

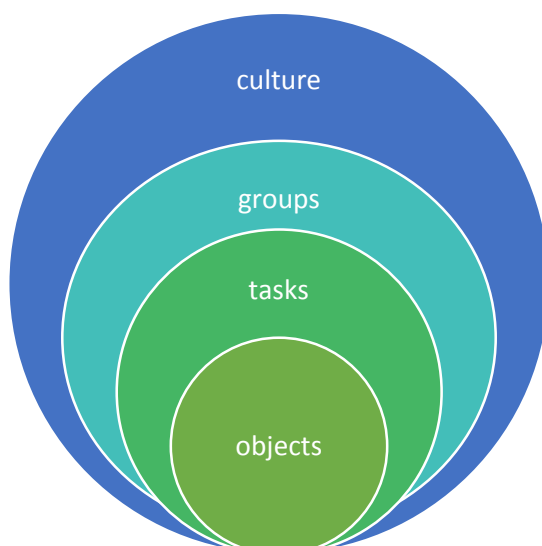


Fig. 5.7 Barris model of environment

(i) Objects

(Note: where italics are used, they imply direct reference to one of Corcoran and Gitlin's principles)

Availability refers to accessibility of objects in an environment. Therefore, clutter, extending to visual clutter, should be avoided, and an individual presented with familiar objects specific to the task in hand. Frail elderly people are observed to create “control centres” in their living-space with useful objects close to hand, both visible and accessible. This should be accommodated in the room design, including by creative reinterpretation. *Complexity* refers to environmental information. When designing for a person with dementia, complexity with respect to objects is not desirable, in order for that information to remain accessible to the user. These two principles, taken together, would suggest that available environmental controls should be minimised, presented clearly, and located where they are readily visible, and easily accessible, in relation to the performance of any given task. This is also in keeping with the more general concept of minimalism in interface design, referred to in Chapter 2. The combined principles also support inclusion of automated environmental controls, some of which are already in use commercially, though in a less comprehensive format. Where a room management system based on networked sensors is included, actuation can be designed in response to a variety of inputs. In terms of the user, these should include data identifying user position within the space, and information regarding the task or activity being carried out. These can be established by a combining and processing data from wearables, if used, and embedded sensors. The use of simplified or automated interfaces is in fully in keeping with the idea of the “Disappearing Computer” (Streitz, N., Nixon, P., 2005), where applications, sensing and associated networks are subsumed into a familiar physical context. A care environment where user needs are more complex and variable, and user ability is impaired, has the greatest capacity for the user to benefit from such an approach. *Flexibility* regarding use of objects is *not* desirable: objects with one clear function are preferred; conversely, controls with multiple options should be avoided. This excludes use of manual remote controls with multiple switches, or Graphical User Interfaces (e.g. a touchscreen) with multiple

options or icons. One suggestion is that a combination gestural/graphic interface might be employed, where options for selecting icons are reduced to FORWARD/BACK/ START/ STOP, so that only one icon at a time is presented, and full-hand gestures are used to scroll between icons to activate a limited number of preset options. Lack of flexibility in use of objects significantly distinguishes this user-group from other populations, and from general assumptions of what constitutes “good” design” of interfaces and interactions. The principle regarding flexibility also supports a case for complete elimination of controls in cases where there is no overt benefit being sought from engaging the user directly. However, there is a fine line to be trodden between ease of use, and lack of stimulation and engagement, or a negative perception of control of one’s own environment. The advantage of an intelligent and responsive control system is that it might be designed to adjust not only to an individual user’s needs and preferences, but that it can be further altered over time in response to changing user status in terms of cognitive and physical ability. Rather than remove all challenges for the user, at risk of under-stimulation, and undermining of remaining cognitive ability, the system should be adjustable for best fit at a given time. Provision should also be made for a carer to adjust system controls, taking into full account user reaction and use patterns as established by the system. This may be necessary only in a set-up situation, on the basis that the system can also “learn” from these inputs.

Corcoran and Gitlin also identify a need for the home environment of the person with dementia (in this case applied to the residential setting) to include objects which have “*Symbolic Meaning*”, which serve to reinforce an individual’s sense of identity. Such objects acquire additional importance for the person faced with identity loss. Symbolic meaning may be bestowed by the “*presence of age-appropriate materials and successful end products of a highly meaningful activity are important in maintaining ego integrity as an outlet for expression of personal identity*”. Corcoran and Gitlin define *Symbolic Meaning* with reference to “*an object's representation of values, such as prestige, sexrole, identification, age-appropriateness, and independence.*” This particularly refers to objects associated

with activities which hold personal meaning, and are self-affirming, especially referring to objects from a person's earlier life, in this context, prior to the move to residential care. As before, the physical setting should be conceived and designed to accommodate some, or the most important of these objects, and their related activities. In the context of one's own room, as well as larger items, such as furniture, which are catered for by additional space, provision can readily be made for the inclusion of personal music, photographs, or reading material. This is greatly simplified by the progressive digitisation of media. Though this format may not be familiar, or acceptable, to a majority of the current cohort of elderly people in care, is it readily conceivable that a person moving to a care setting in future years will be able, and willing, to bring a lifetime of memories and preferences, including personal music and image libraries, on a data stick, or be facilitated in downloading them, as required from the "Cloud". This in turn relieves the pressure on the room to accommodate quite so many physical artefacts. If the room is thus rendered "hyperfunctional" through responsivity and digitisation, physical space is created for the intimate and personal, for the crafted and handmade. For a person with dementia, it is preferable for such applications to be accessed through recognizable object-based interfaces with simplified controls, for example, through digital photo-frames. The room can be enabled to adjust itself to personally preferred settings, previously established by data input or by monitoring, with a personal music collection, eBooks, family photos, internet browser bookmarks, colour preferences, and so on, all immediately accessible. In this manner, place-making might be supported by personalization, through the medium of personal digital data. John Ziesel, writing in "I'm Still Here", describes making what he calls "memory-boxes" at the entrance to each resident's room in residential care for people with dementia, containing objects significant to that resident, and preferably selected by the resident. The Memory-Box assists the person in identifying her own room, and stimulates reminiscing. In this proposal, the room itself might, in effect, also become a sort of three-dimensional "memory-box" through the use of existing digital technologies. This might be achieved most easily by actuation of a personalised media/data portfolio through recognition of a specific user. Applications which utilise biometrics, e.g. The "Smart Floor" (Orr, R. J., Abowd, G.

D., 2000) developed at Georgia Tech, already allow the possibility of a space or building “recognising” an individual, and on that basis querying whether they wished to opt in or out of personalisation of the space, through linking to their own remotely-stored data. Use of personal biometrics for access to a databank protects its security: only the real owner is enabled to gain access. The current cohort of elderly people is already adapting to such technologies; in time there will nothing remarkable about such material being stored and accessed in digital format as a matter of course. The same capacity for personalisation is of obvious benefit in temporary accommodation, or in the workplace, and in short-term healthcare settings. In some senses, some aspects of “home” or “placemaking” may thus become a portable concept.

The essence of the proposed model is, that whatever the potential of new technologies, they must accommodate the familiar, as well as being framed by it, rather than be treated as a wholesale replacement. While this is very obviously the case when designing for a population with dementia, on reflection, it seems a measured approach that might be appropriate in many contexts. Parallels might be drawn with the rapid and recent emergence of near-ubiquity, in developed countries, of mobile technologies. They have moved rapidly from the novel to the commonplace, so much so that many people are now at the stage of consciously and selectively ridding themselves of superfluous ICT and mobile applications, in the form of social networks, and so on. If designers and technologists take care to first apprise themselves of user needs, it might be hoped that embedded systems will learn from the mobile web experience, and be more selective about how and why embedded interaction is conceived and realised. It has become very evident during the course of the literature review that digital technology, and in particular sensor networks, can provide the designer of the built environment with an almost inexhaustible “box-of-tricks”. However, it bears stating, based on the mobile web experience, that novelty, surprise, and superfluity of choice might not be entirely desirable characteristics in a domestic setting, and definitely not where the occupant is especially vulnerable. This proposal therefore consciously aligns itself

with Malcolm McCullough's call for a "quiet architecture" (McCullough, 2004), enabled and supplemented by networked systems. In such an architecture, the user, and the set of user interactions with a specific context, stands at the heart of interaction design and responsivity, and serves to further reinforce ideas of context in architecture. In this proposal, the room, which forms the immediate context, belongs to a specific individual, in a very particular fashion, where interaction with the environment becomes an ongoing personalised relationship, made possible by sensor-actuated responsivity. Digitally-enabled personalisation, at the level of the intimate, can thus support the integrity of the individual, and act as an outlet for expression of personal identity.

(ii) Tasks

In the Barris model, a "task" refers to any sequence of actions which satisfy "external societal requirements of internal motives to explore and be competent". Tasks in a care setting include self-care or leisure activities. The task layer has five dimensions: *complexity*, *temporal boundaries*, *rules*, *seriousness/playfulness* and *social implications*. Varying these dimensions influences arousal in the individual (i.e. the person's inner state), and environmental press, and thus affect the individual's choices about behaviour. Loss of physical and cognitive ability through ageing or dementia affects a person's ability to adapt to varying environmental press.

Complexity refers to the required skill level and number of steps needed to complete a given task. Where the end-user is a person with dementia, task complexity should be simplified or broken down into smaller steps to enable successful completion. In relation to using an interface or application, interfaces/controls, where included, should also be designed so that only repetitive gross motor activity is required, in order to reduce task complexity, and might also incorporate tactile elements as a guide where appropriate. (Levy, 1987) (Berman, S., Rappaport, M. B., 1985). This suggests possible solutions to interaction design

which include including simple gestural interfaces or large-scale, easily recognizable touch-screen icons. Simplified, concrete verbal instruction might also be utilised, though should relate in an obvious manner to a specific interface and a readily-identifiable interaction on the part the user. A need for reduced complexity also supports the case for automation and machine-learning in this context. How this is to be achieved, i.e. how the interaction is designed, is dependent on the task in question and the characteristics of the user.

A further proposed intervention in the task layer is the provision of *Temporal Boundaries*. This may be supported by “providing special attention to a routine with frequent rest breaks in order to help reduce possibility of surpassing the stress threshold”. The “catastrophic reactions” of people with dementia, referred to previously, result from exceeding a much-lowered threshold for stress. These include, for example, aggressive outbursts, or the restlessness associated with sundowning. This can be mitigated by providing a dependable routine, where activities follow one another in an expected order. Daily routine should also allow for rest breaks for recovery, and restoration of attention. While sufficient room size immediately affords the possibility of private relaxation, this might be actively prompted by providing environmental cues for relaxation and restoration, including actuation of stress-relieving applications at intervals based on the user’s own behaviour patterns. This will be discussed in detail in the following chapter. Such cuing for rest breaks might be designed to operate at appropriate personalised times and intervals, established over time by machine learning from sensed data.

Many people with dementia experience temporal disorientation, including an inability to remember sequence of events, even on a short-term basis. Therefore, supporting temporal orientation, and circadian rhythms, through reinforcing diurnal and other routines, can also facilitate user competence (Oakley, 1988) (Hall G, 1987). There are a number of ways in which this might be addressed in the personal life-space of a person with dementia, including by “designing in” environmental

clues for temporality, e.g. provision of cycled lighting to reinforce circadian rhythms, which can assist in establishing *temporal boundaries*.

While so-called “biodynamic” lighting systems are commercially available for specific use in healthcare settings, in reality they are very primitive, using two colours of light only, which does little to emulate the infinite variation in natural lighting as experienced outdoors, where intensity and colour vary according to time of day and season, and other factors, including cloud cover. It is suggested that a truly dynamic system would combine a flexible lighting scheme allowing for variation in colour temperature, with an ambient visual installation, thereby beginning to accommodate the possibility of constant and infinitely variable change within a daily or seasonal framework. Seasonality might be reflected in lighting and through design of the visual environment, including by varying the colour palette of visual installations on an interactive wall, as described in Chapter 6. Lighting should include seasonal compensation for falling light levels and lack of bright light by inclusion of early-morning bright light, or blue-green lighting. The latter, or indeed any significant variation in colour might best be provided unobtrusively through ambient visual content.

Rules: People with dementia make mistakes, and often do not recognise or correct them, but may nonetheless be upset by their consequences. They still recognise the “emotional backlash” resulting from rule-breaking in a rigid environment. This dimension suggests that achieving tasks should be facilitated in a flexible manner, with a variety of options. Highly flexible rules permit safe exploration of the environment. The flexibility enabled by sensing and sensor-actuated response can permit a user to safely explore how an environment operates, without rigid “rules”. The possibility of making a “mistake” with negative consequences can be minimised through thoughtful design intervention: for example, taps might automatically switch off when water levels in a basin reach a specific level. Coupled with controlled water temperature, the same intervention might assist a person with dementia in being able to independently bathe for longer, or with a feeling of more independence and control over the situation, and less likelihood of “rule-breaking”.

The same type of intervention addresses the task layer dimension of *Seriousness/Playfulness*, which requires that “*Tasks must lack negative consequences and be non-anxiety provoking*” The balance between seriousness and playfulness is influenced by expectations of the person, and by the context. In designing for certain activities, for example, reminiscing using digital media, this dimension might imply introducing an element of game-playing into human-computer interaction; it would also appear to strongly suggest simplification of other interfaces to the point that they are invisible, and require no active input on the part of the user.

The *social dimension* distinguishes between tasks that are cooperative and competitive, strongly favouring the former; in addition, the outcome of a task should benefit the individual user, or one “highly-approving other”. There is also a distinction made between the private and public nature of activities. The social dimension can be catered for by facilitating appropriate private activities in the room setting. Activities include an identified need for low-stimulus activity, including “daydreaming”, which Rubinstein regarded as necessary for defining and maintaining an individual’s identity (Rubinstein, 1989). As well as being supported by providing for example, sufficient space and views out for observation of external activity, this might be enhanced by digital applications, for example, a video feed from shared or external spaces (Placeholder54), as well as by cues for relaxation, such as dimmed lighting, or actuation of a restorative visual/ multimedia application.

(iii) Social Groups and Organisations

The third layer, *Social Groups and Organisations*, and its associated dimensions of *size, function, permeability* and *structural complexity* relates more to the overall care setting than to the individual’s room. However, it is worth noting, with reference to the previous chapter, that increased unit size inevitably leads to increased structural complexity not only in terms of how the care setting functions,

but also in terms of architectural complexity. This can militate against comprehensibility and manageability. While permeability refers, in Corcoran & Gitlin, to the degree to which a family is open to external supports, it might also translate to how an entire care setting views itself, and is perceived in relation to the community in which it is located. The architecture of a care setting can either promote or limit connections to the greater physical and social context. This has been witnessed on a number of occasions during the author's professional career. In one case, after a move from a traditional institutional setting, in a Victorian psychiatric facility, to a purpose-designed prototypical residential care setting consisting of three clustered units, staff reported that relatives who had never been known to visit began to do so. They also reported improvements in residents (in this case, with moderate to severe intellectual disability) where it had been long presumed that there was no further capacity to learn in the individual in question. In relation to future design work, these outcomes should ideally be formalised into research outputs.

(iv) Culture

The *Culture* layer in the Barris model refers, in Corcoran and Gitlin, to family culture. Here is interpreted as the culture of care. It includes the dimensions of the *Nature of Work and Play, Space/Time, and Transmission of Knowledge and Cultural Values*. What is significant in the context of design is a conscious recognition of expectations of the user/resident, both from a resident and carer perspective. Architecture and interaction design should aim, as part of the culture of care, to maximise the resident's abilities to make decisions about activities, including meaningful activities, taking care not to allow a limiting view of the person as a dementia patient to rob the person of status and independence. In a broad sense, the extension of independent function in relation to the environment, where enabled by responsiveness, facilitates continued autonomy and choice. Once again, the simple device of sufficient space provision forms the basis of maximising choice over activities, including allowing for, and valuing, non-productive time.

Automation and elimination of manual controls, when integrated with architectural design, can do much to achieve these goals.

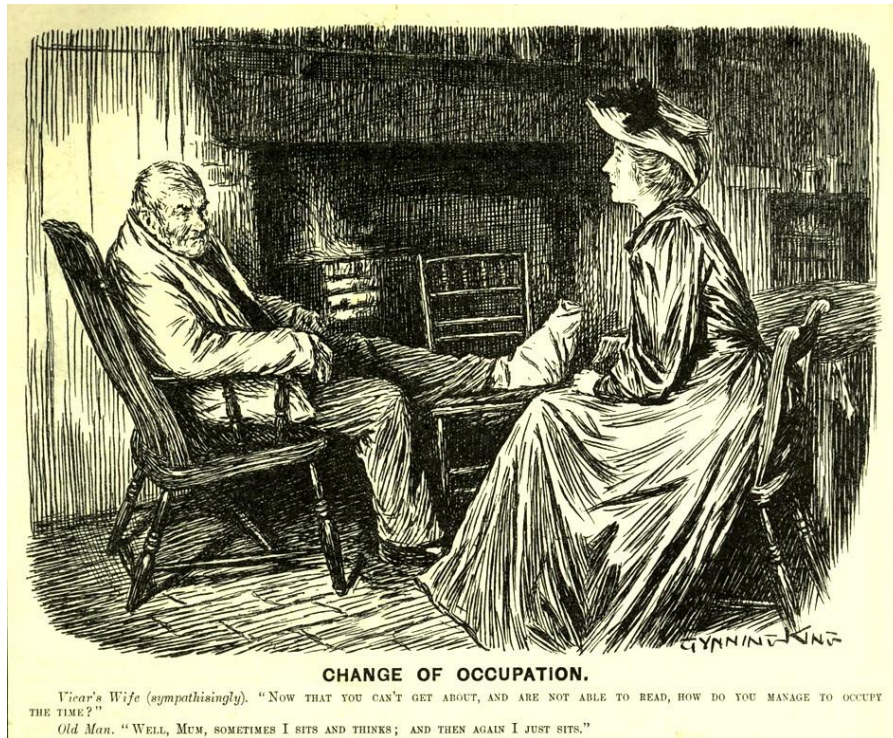


Fig. 5.8 Non-productive time.....

(Punch magazine)

KEY CHARACTERISTICS OF AN ADAPTIVE SALUTOGENIC ROOM

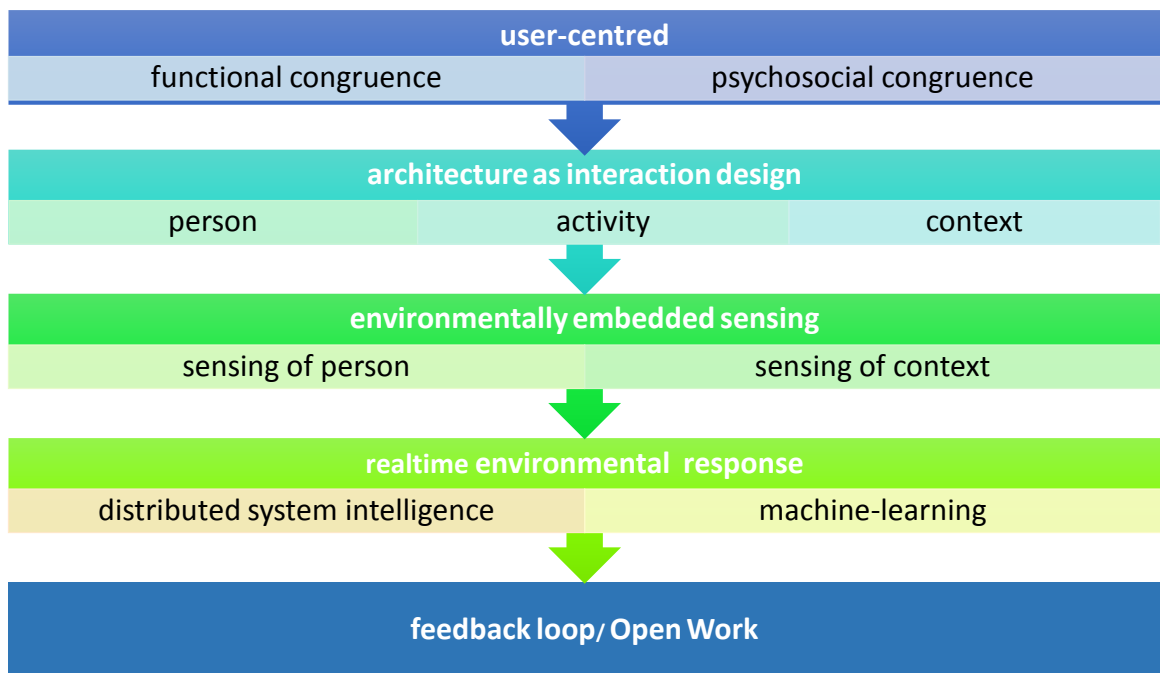


Fig. 5.9 *System characteristics of an adaptive salutogenic room*

The key characteristics of the MyRoom model may be summarized as follows:

Firstly, the design of such a space must be *user-centred* in the most fundamental way, so as to maximize both functional and psychosocial congruence. In the case of this user, environmental enhancement is achieved through the physical embedment in built environment of sensor networks which support *responsive adaptation*, so that architecture is re-cast as *interaction design*, and so guided by considerations of *person, context and activity*. This supports direct interaction between person and environment, with a “natural” interface based on direct and contextualized sensing of the person. For some applications, haptic or gestural interfaces may be preferred in order to support reinforcement of self-identity. To fully address issues psychosocial congruence, *contextualised sensing of, and response to user affect* becomes a necessary component of the model, facilitating both environmental response to the user’s affective state, and, by the same technological means,

measurement of the efficacy of any environmental intervention by observation of changes in user affect. This evaluation might be applied to interventions intended to support either functional or psychosocial fit. Any sensing of the person must be contextualised in order to accurately interpret sensed data. To create meaningful and useful environmental adaptation, *real-time response* must be enabled. This is potentially feasible only where *system intelligence*, informed by *machine-learning*, is a tacit assumption. Environmental response which is intended be therapeutic closes the *feedback loop* by acting on the person, at the same transforming architecture into a truly open work, where dynamic user interaction becomes an implicit component of aesthetic and other design outcomes.

The MyRoom concept envisages that the personal life-space (here, the long-term care room) will be designed to include a comprehensive embedded responsive system, with multiple networked sensors, allowing continuous activity-aware and contextualised sensing of a user's psycho-physiological state. In the context of architectural theory, the proposal represents an extension of theories of responsive architecture as described by Nicholas Negroponte (Negroponte, 1975), and a fusion of research approaches from affective computing and responsive environments, creating a new paradigm for user-centred responsive architecture, which is generalizable to all building types. The sensing of affect, and most specifically, indications of inappropriate stress in this scenario, is considered key, because of its specific role in wellbeing, and its particular significance in dementia, both on an initial causal basis and also in the ongoing of therapeutic care of the person with dementia. Whether or not stress is appropriate will be established over time by simultaneous sensing of affect, activity and context, using multi-modal bio-sensing. Sensing of positive affect can also be used to coach system learning of preferred interactions and outcomes. In summary, sensor networks will track subtle changes in behaviour and emotion, using a combination of bio-sensing, together with monitoring of activity and location, to build up a comprehensive and contextualized picture of an occupant's emotional state on both a day-to-day and longer-term basis. Of necessity such a system must be conceived of to include intelligence, in

order to be able to act appropriately and autonomously, where deemed appropriate, on the sensed information received. While such a system will be guided by machine learning, it should include for direct intervention to the system by a carer. While use of monitoring might be construed in some situations as invasive, in the context of a very vulnerable and incapacitated individual, this may not be the case, if the benefits to the person outweigh loss of privacy. Adam Greenfield hypothesizes that *“Everyware is strongly implied by the needs of an aging population in the developed world”* (Greenfield, 2006). Embedded continuous sensing is in many ways far less an invasion of privacy and personal space than the always-open door, the institutional observation-window (in acute hospitals), or the forced socialisation of the shared living-room. Real-world explorations of architecturally embedded digitisation and response are currently being researched. Examples include AwareHome (Georgia Institute of Technology), and inHaus2 (Fraunhofer Institute). However, neither example addresses the possibilities inherent in affective responsivity. *“The Building Is....”* (Hide & Seek, 2012) displays a more playful attitude to architectural responsivity, through an opposing approach where the building is ostensibly made sentient through the active involvement of occupants.

While the physical environment, enhanced by technologies, can move closer to accommodating the functional by offering the possibility of automation of controls, personalised and sensor-based response has the potential to compensate not only for loss of physical function, but to a degree for other impairments, including the loss of ability to articulate functional needs, or to successfully communicate emotional state. The possibility exists in MyRoom of externally illustrating, or communicating, changes in emotional state by initiating visible environmental change in response to sensed data. The system might thus communicate that status not only to a carer, but potentially enable the occupant to recognise that her inner state has been externally communicated and more importantly, acted on, by a carer or by the system. Carefully-considered interventions might offer the possibility of reducing the likelihood of stress overload, where it arises either from a

mismatch of environmental press and user competence, or an inability to make needs understood in a conventional manner. The removal of some of the burden of care from the user might then afford space for more personal and social care.

Incorporation of interactive applications designed with the specific user in mind can also offer more opportunities for self-actualisation, where systems use haptic interfaces, or initiate readily-observable change in response to gesture. Further possibilities for active therapy through embedded biofeedback applications also exist. Real-time tracking of affect, when contextualised, allows the system to build up a picture of the user's diurnal patterns. Where there is a pattern of increasing stress and a catastrophic events, the system can "learn" to anticipate such events from sensed data indicative of changes in affect, and respond appropriately, in a timely fashion, for example, by alerting a carer, or by actuating an intervention within the room environment, in the hope of averting an adverse event. If such events tend occur around a specific time of day, intervention might occur prior to deterioration in the user's status. Here, the input of a carer would be most useful. This can be described as "interactive reinforcement learning". User feedback, in the form of sensed affect, can also be used to inform machine learning by promoting or demoting actions/adaptations on the part of the system.

It is evident that many of the suggested interactions and applications might also be relevant in other settings, including other residential care settings, and might also be transferable to different user-groups, with either physical or cognitive impairment, or both. The guiding principle of ease-of-use, to support inclusive design, makes the same, or very similar solutions, readily applicable to a much broader cohort of users. In any long-term setting, the ability of the system to modify itself in response to user requirements is a key characteristic, both with respect to designing for functional and for psychosocial congruence.

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Chapter 6: MyRoom II

- **A proposal for A Dynamic Lighting Design to support functional and psychosocial congruence**
- **A Restorative Visual Intervention**
- **MyRoom Demonstrator**

Introduction

Chapter 5 has set out design principles for the personal life-space of an elderly person in a supported residential setting, incorporating a set of recommendations for environmental interventions made in the form of architecturally-embedded interaction design. Continuous real-time response is made possible through deployment of embedded wireless sensor networks. The essential nature of interactions is determined as much by the technologies as by the architecture itself: without sensing and ICT, there is no possibility of active and considered real-time response to the occupant. The final form of any individual embedded design intervention will equally be a function of the technologies used in its creation. Thus, the creative possibilities of the symbiosis between architecture, and ICT and digital technologies are almost limitless, and only beginning to be tentatively explored. Where there have been aesthetic explorations, they have tended to be superficial, and often closer in their nature to art installations. When design intentions are primarily functional, aesthetics have largely become a secondary concern. The best examples of a genuinely symbiotic relationship between architectural design and sensor technologies, are to be found in responsive façade design, where successful integration of technologies necessitates an essentially architectural approach. Here, engineering for functional reasons becomes close to indivisible from aesthetic outcomes, so that there is inevitability to consideration of aesthetics, as an intrinsic element of the overall design. Where kinetic facades respond to varying environmental conditions, the variation in the appearance of the façade inevitably tracks variation in the environmental context, so that while that facades might be highly-engineered, and machine-made, their inherent mutability endows them with

aesthetic qualities which relate very immediately to those of their ever-changing natural context. The MyRoom proposal effectively turns the concept of real-time aesthetic variability in response to environmental context, inside-out. The concept becomes one of generating real-time internal environmental response to the person, which is moderated in response to user activity and needs, as determined by contextualised bio-sensing. In order to maximise congruence in the personal room environment, personal needs are assumed to be psychosocial as well as functional, so that sensing of, and response to, user affect become a critical component in the ongoing transaction between the person and her immediate environment. The proposal for a responsive architecture of this nature is specific to user, context and activity, in the manner of interaction design at non-architectural scales. As such, it reflects transactive approaches to person, environment and occupation found in occupational therapy (Law, M et al, 1996). Designing for other users, in different architectural contexts, will inevitably produce varying, and even radically different proposals, and ultimately, many diverse built outcomes of responsive architecture. This proposal represents a first step in the direction of envisaging and making an affective responsive architecture. Affective responsiveness of itself constitutes a new paradigm for responsive architecture.

The previous chapter has identified a critical need for sensory change and variability in the internal built environment for the person with dementia, such variability being identified as an essential to supporting human functioning and wellbeing. For an elderly person in residential care, or supported housing, the personal life-space must be designed to provide for this, taking into account in that the occupant may be confined to her room for considerable tracts of time, both by choice and through impairment, and furthermore, during palliative care. The question then is, in this context, how to go about designing for provision of such characteristics, and continuing to make them accessible in all situations, even in the case of the inevitable cognitive decline associated with dementia. This chapter will explore, in some detail, two linked environmental interventions, which create variability, primarily in the visual environment of the room, but which also suggest further multisensory interventions. They are intended to support both functional and

psychosocial congruence. The necessity for its provision in this manner, which is supplementary to any intrinsically supportive characteristics of the architecture, arises directly out of user need in the specific context. The proposal implicitly addresses issues of reduction of stress, and of attentional restoration, both seen as appropriate to user and context, and both to be achieved through sensory change and variability, where they are moderated in a considered fashion. It also offers the possibility of translation to other contexts, where concerns of de-stressing and attentional restoration are also paramount. Environmental response takes place at the scale of the “personal life-space”, and is conceived as an integral part of the design of the room environment. It must immediately be acknowledged that the successful realisation of any such environment will be a long and complex process, inevitably and fundamentally interdisciplinary in its nature. ICT offers to architects various means, to ends which were until recently, undreamt of, while architecture offers, in return, many visions of what those ends might encompass. The inherent creativity of many engineering disciplines must equally be acknowledged: if no-one had imagined sensor technologies, it would not have been possible to begin to imagine responsive architecture in the fashion that Negroponte envisaged it.

In the manner of the physical design interventions cited in the previous chapter, the same responsive design intervention may serve more than one purpose. The following proposals for enhancing psychosocial fit are synthesised from research findings in behavioural psychology and other areas of research. They represent, together with the overall proposals for the design of a personal life-space for an elderly person, as set out in the preceding chapter, a specific and localised case of responsive architecture, where architecture is framed as interaction design. The existence of an architectural context necessitates a holistic approach to design, so that any proposal must involve due consideration of the total environment, as well as more detailed consideration of individual task-based interactions. In effect, the room, or personal space becomes the interface between person and system, where the dynamic system managing the ongoing transaction between person and environment is itself viewed as an integral component of the design concept.

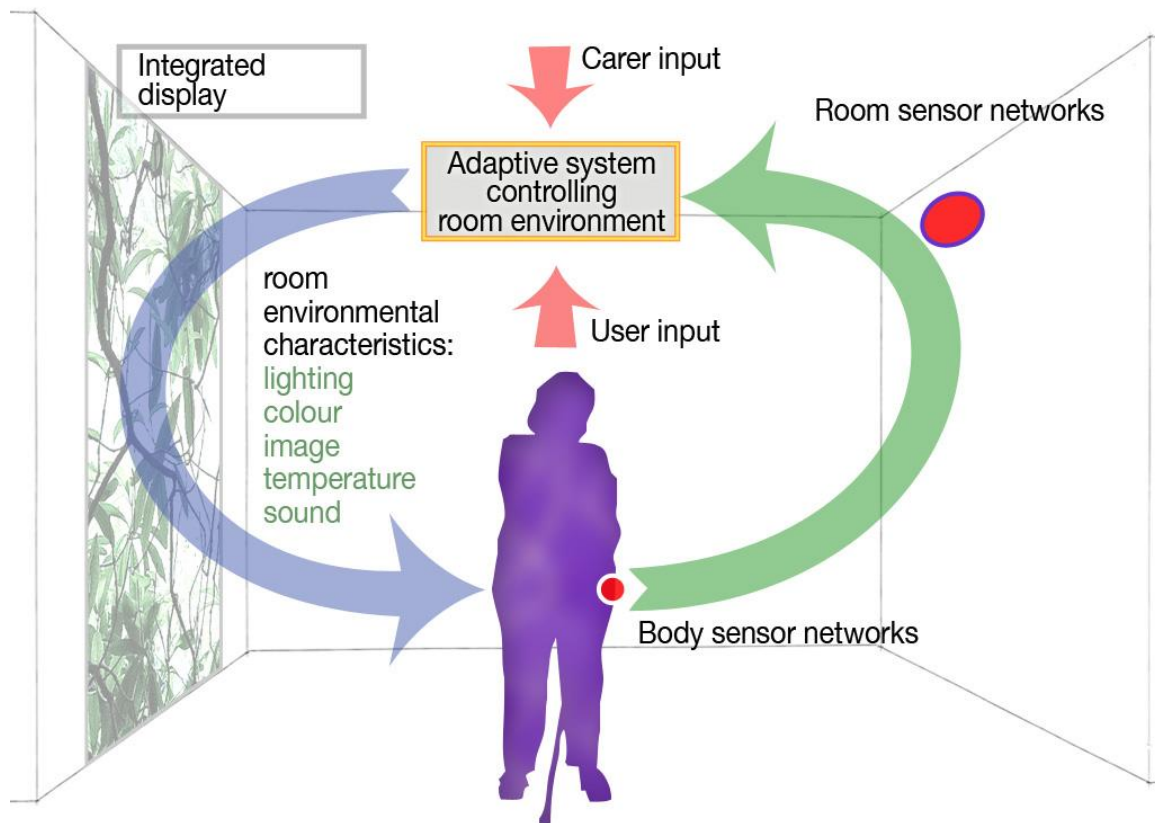


Fig. 6.1 MyRoom

MyRoom

The first proposal is for a dynamic lighting system, and the second, a design proposal for a therapeutic visual intervention, which complements a variable lighting system. Both are managed in tandem by the system which manages the room environment, as part of a BMS, but which also takes into account, in managing the environmental context, user activity and affect, so as to address issues of both psychosocial and functional congruence. The BMS is also presumed to manage other applications which moderate the room environment in more functional terms; these are not dealt with here. Interventions are envisaged as being responsive to user's affective status, which is determined through contextualised sensing of the person, with ongoing real-time response refined by machine-learning. Response to affect becomes a critical component in the ongoing dialogue between user and environment, thus personalising environmental response in a fashion which encompasses more than the functional. While the focus in the proposal that follows is on visual response, there is no reason why a

therapeutic application should not include sound and/or music, and many reasons why it should. There is much research to support both the therapeutic use of music, and the benefits of a multisensory approach, in the design of care environments. The combined proposals suggest a means of achieving Neutra's vision of a "biologically perfect interior by technological means" (Neutra, 1954), by a synthesis of technologies which were not in existence at the time he proposed it. Proposals for the creation of visual content likely to have therapeutic effects, are derived from the literature review. As well as a de-stressing element, restoration of attention is sought, as an appropriate aim for a user with cognitive impairment. From a broader perspective the proposal is seen as contributing further flexibility to a multi-functional life-space. The proposal is followed by a brief account of the making and testing of a partial prototype.

A PROPOSAL FOR A DYNAMIC LIGHTING DESIGN TO SUPPORT FUNCTIONAL AND PSYCHOSOCIAL CONGRUENCE

While the need for provision of dynamic variability in internal lighting schemes is already recognised as being of benefit, in healthcare settings, in schools, and in human habitations in general, such systems as are available to date offer little by way of real variation, in comparison with the natural environment. There is also very little precedent for their use in residential care architecture, any focus so far having been on use in acute care settings, despite the fact that over a period of months or years spent in living accommodation, any detrimental effects from lack of exposure to sufficient light, or from exposure to inadequate internal light, is likely to accumulate. The need for compensatory measures in residential care buildings, where there is a likelihood of either cognitive or physical impairment in users, is more pressing than in domestic settings. The built environment of care may impose restrictions on use of space and freedom of movement, in sometimes of necessity in terms of provision of a safe environment. At the same time it has been noted earlier that well-managed use of sensing might enable personal freedom of movement while also ensuring safety. In a home setting, a user will

generally have greater freedom of movement. It has also been recognised that the personal life-space of the elderly person, even in the home “shrinks”, especially with the onset of dementia. Diminishing life-space correlates with loss of mobility and onset of frailty (Xue, Qian-Li et al, 2007), and also with cognitive decline (Crowe, M et al, 2008). An appropriate compensatory lighting system may provide a means to extend the time-frame for living with greater quality-of-life and wellbeing in a home setting, in addition to being of particular benefit in supported accommodation. The issue also begs the question that if dementia increases the likelihood of a person staying indoors at home, and rarely venturing out, to what degree is loss of temporality in dementia a consequence of insufficient exposure to daylight, and to what degree can prosthetic internal lighting compensate? At best, current lighting schemes in care settings often do little more than meet very basic functional requirements, and that often only to the extent that sufficient overall illumination is provided. This falls far short of what might be rightly be deemed appropriate to meet human needs in general, and all more so for a user-group with cognitive and sensory impairment.

Elderly people in the first instance require higher background lighting levels than the general population (Placeholder52). Brighter lighting is needed to compensate both for age-related deterioration in visual acuity, and specific age-related conditions, such as cataracts. This has only very recently recognised in terms of developing recommended lighting standards for care settings. Research has also indicated that higher levels of ambient lighting are needed to achieve activation in elderly people, and that high-intensity light at the blue end of the spectrum can ameliorate symptoms of restlessness and reinforce circadian rhythmicity in people with dementia. (van Hoof, J et al, 2009) While many researchers advocate uniform lighting levels throughout a dwelling, in order to avoid cognitive overload from sudden environmental change, this approach does not provide any sensory variability, and the few built examples based on the research unfortunately retain an overwhelmingly institutional appearance, which works against an overall aspiration towards a “homelike” and familiar environment. The solution may lie in a more nuanced approach to lighting design, where there is a higher level of ambient

lighting, but with subtle local or temporal variation to reflect user activity and time of day.

Provision of a lighting system which has the capacity for dynamic variability seems critical to address issues of psychosocial congruence, bearing in mind the extended nature of the user's exposure to the personal room environment in long-term care. Static colour and lighting do not begin to adequately address human needs, even for a general human population. However, a person confined, for whatever reason, to a smaller spatial domain is automatically more vulnerable to the negative effects of a lack of sensory variability, unless some means of compensation is sought. Neutra is downright scathing about the suitability of static colour, and static lighting, in relation to meeting physiological need: "any static color, or color combination is, physiologically speaking, unfit" (Neutra, 1954). Once more the particular situation of the person with dementia, and the consequent loss of ability to interpret, interact with and manipulate the physical environment, presents particular issues. Many of these might be solved simply by providing more personal social space, so that a person's own preferences can be established and respected, as it will always be difficult to mediate an optimal solution in shared spaces. This echoes known issues with use of statutory standards for accessibility in the built environment, which on occasion fail to meet the needs of individual users with disabilities, including when conflicts arise out of other statutory obligations. While design problems in general can be regarded as "wicked" (Conklin, 2006), in that they are ill-defined, difficult to resolve, as they often must address changing or conflicting requirements, Universal Design can be especially so. There appears to be little option currently, when designing for a public or semi-public domain, but to cater for an "average" range of ability (or disability), albeit an extended one. Sensor-actuated adaptation of fittings provides a likely route to more inclusive solutions.

In an external environment, or an internal environment with good natural lighting, colour and intensity of natural light offer subtle cues as time of day. While natural

light is described as white, it actually varies over the course of a day, and also seasonally, while, at the same time, our eyes adjust so that colours of objects appear constant to us in varying light conditions. Bright early morning light (which is closer to the blue end of the spectrum) is critical in entraining circadian rhythm; similar effects can be obtained using artificial blue light (Brainard, 1998). The intensity of midday light provides a cue to eat; the movement towards the red end of the spectrum of evening light provides a cue for rest and sleep. Such environmental cues, which entrain 24-hour biological cycles, as well as annual cycles, are referred to as *zeitgebers*. Temperature is also a zeitgeber, as are other external influences, including events like mealtimes. For a population with dementia, and its associated and typical loss of temporality, the emulation and reinforcement of natural change and variation in internal lighting, to supplement natural zeitgebers, has significant potential to support wellbeing. Disturbed circadian rhythms also are associated with mood disorders (Li, J. Z., et al, 2013) and SAD, which it is thought may occur from an absence of sufficient zeitgebers. Daily rhythms, or lack of them, affect mood. Time of day also affects task performance, and here also, there is potential to support cognitive function, through conscious reinforcement of circadian rhythms. (Blake, 1967)

Characteristics of a psychosocially and functionally supportive sensor-enabled lighting system

A lighting system supportive of both functional and psychosocial congruence should therefore incorporate as many as possible of the following features, which can be considered compensatory, or prosthetic:

- A higher level of ambient lighting, to compensate firstly for loss of visual acuity due to age-related impairment, and sufficient to achieve activation, at appropriate times of day (van Hoof, 2009)

- Variable supplementation of daylighting as and when required, in response to varying external lighting levels, and resulting internal ambient levels, to provide enhanced levels of ambient lighting.

- Automatic intelligent actuation of variation achieved through sensing of context and/or person, as appropriate

- Pre-programmed diurnal and seasonal changes in lighting colour and intensity, that act as zeitgebers, to reinforce temporality, e.g. dawn simulation, cool morning light, warm evening light. The variability associated with external environments might also be emulated by inclusion of a constantly but subtly-changing embedded video content, described in more detail later.

- Appropriate task-lighting, with adjustment for colour temperature as well as intensity.

- Night-lighting which uses an infra-red source only, to avoid disruption of melatonin production, in support of circadian rhythms.

- The possibility of using lighting with a safe UV component to compensate for lack of exposure to sunshine in winter months and its associated effect on Vitamin D levels might be investigated.

Providing dynamic variability in a lighting system requires, at the very least, that both colour and intensity should be variable, and programmable. While some commercial systems have variability in colour temperature of white light, they do not allow introduction of other colours of light if desired for any reason. The colour range is dictated by the type of light source, and the sophistication of the controls moderating changes in colour temperature and intensity. Systems on the market tend to rely on two light sources only, so that the range achievable is limited by the colour temperature of those sources. However, LED lighting technologies have

arrived at the point where it actually feasible to provided nuanced variation controlled by software, across a broader range of wavelengths which more closely match the colour temperature of natural light over the course of a day. Scope therefore exists for development of far more complex lighting systems, controlled by intelligent sensor-based building management systems (BMS), and capable of addressing both basic functional needs and psychosocial well-being. Use of sophisticated LED lighting systems to date has, again, been in pursuit of aesthetics rather than for compensatory of therapeutic reasons. A holistic compensatory lighting system might be approached in the first instance by designing so that not only are both intensity and colour capable of more subtle variation over the course of the day, but that variation is underpinned by a consideration of how intensity and colour temperature and might appropriately support preferred activities at particular times of day. While there are references in the promotional literature for commercially available systems to their use in various contexts, the potential for this particular user-group, in residential care, seems to have been almost completely overlooked.

Rather than providing conventional light-switches, automated controls can be used, as described in the preceding chapter, responding to user activity and position within the room, as well as to ambient external lighting conditions. For example, task-lighting might be switched on in response to user proximity to a chair or desk; the colour temperature of the light-source should aim to maximise cognitive functioning. Bathroom lighting might be activated by RFID, as is already commonplace in lighting systems, but might also incorporate bright-light treatment in the early morning. Bedside lighting can also incorporate proximity-activated switching, but perhaps only in late evening, which would also serve to provide a temporal clue for bedtime. Night-time lighting should be in the red part of the spectrum, to avoid disruption of melatonin production. So, for example, a bedside light might switch on automatically at say, 10p.m., and later switch itself off in response to a specified period of inactivity once the occupant is in bed (in the manner in which some existing commercially available alarms function) and switch on again, using the appropriate light-source, in

response to the occupant sitting up or attempting to get out of bed, which can be detected through use of a mattress pressure sensor. The system might also be programmed to learn when an individual occupant's preferred bedtime is, or to reinforce cues at a suitable bedtime, when this becomes an issue.

Detailed design of such a lighting system is key, not solely in terms of functional provision, but also in relation to how it supports psychosocial function. More nuanced lighting design, which is reminiscent of domestic situations, must be explored, rather than an environment of unfamiliar continuous and uniform brightness, which mitigates against the provision of familiar and homelike environment. All of the features described above also contribute to personalisable and responsive variation.

A RESTORATIVE VISUAL INTERVENTION

“When everything else has gone from my brain.....when all this has dissolved, what will be left, I believe, is topology: the dreaming memory of land as it lay this way and that.”

-Annie Dillard, prologue to An American Childhood

Given the inherent restrictions on mobility, particularly in late-stage dementia, there is a significant case for design of additional internal features that emulate the intrinsic complexity and aesthetic potential of natural views within the room-space, to complement availability of external views of nature. The following is a more detailed suggestion for a visual/ multisensory application, which aims to de-stress and restore attention. It would seem from the literature review that visual content based on natural imagery and fractal patterns should play a part in any proposal for a therapeutic visual/multisensory intervention, and that this approach might be used to further contribute to ongoing sensory change and variability. Digitisation of content and carefully designed programming offers the possibility of continual and inexhaustible variation of content. There are a number of approaches which spring to mind.

What should such an intervention consist of? Based on the review and analysis presented in the opening chapters, the proposal here is for an architecturally-integrated visual intervention, made at the scale of the space which forms its physical context. There is no reason that the intervention should be confined to the visual, though this aspect is explored in some detail. The advantage of a visual intervention is that it might be designed to run almost continuously, but in the background or periphery, as an ever-present backdrop, and come to the focus of attention when required to do so.

Attentional restoration, and an intention to actively de-stress the viewer the user, are prime considerations. It is immediately apparent that such an intervention

might prove useful in many architectural contexts other than healthcare, where the person does not have easy access to the outdoors, to natural views, and is confined to a specific context, such as the workplace, or at a larger scale, the city. Much of the research to date in relation to attentional restoration relates to the context of workplace, with the overt intention is to find a means of increasing productivity through improving the capacity for sustained attention. The other outcome is increased perceived wellbeing on the part of workers, which may be a secondary consideration in the research in question (Peters, R. K., Benson, H., Poter, D., 1977). Ultimately, in addition to attentional restoration, the intervention would seek to induce a Relaxation Response (Benson, 1982) through passive means. The response was described by Benson in a mass-market book of the same name published in 1975, and also in a number of scholarly articles. Benson's techniques are a simplified version of transcendental meditation. However, for a person whose capacity for learning has become impaired, or where a person it may no longer be practicable to teach relaxation techniques, and alternative means must be sought.

Many public spaces in cities are, almost by definition, completely lacking in opportunities for privacy, refuge, calm and restoration. There is no law, written or unwritten, that guarantees that public open space is nearby and accessible, though architects and urban planners may strive to include provision for such spaces. Even then, by their very nature, they may be poorly-configured to afford real privacy when required. Many urban architectural environments only allow for interaction of an impersonal and transient nature, for residents, workers and visitors alike. The personal recedes. Opportunities for personal space and restoration may be few. Stephen Kaplan comments also on the common unavailability of opportunities for restoration: "Restorative environments may be inaccessible because of distance or inclement weather or the health status of the individual in need of restoration. Having an alternative as a supplement to a restorative environment experience or even as a substitute when there is no other alternative could substantially increase the availability of this important component of psychological health." (Kaplan, 2001) The person in palliative care is the most extreme case; one little room has to become an "everywhere", to paraphrase John Donne. Newer workplace design and

working regimes, based on behavioural research, recognise and address these deficits, providing for breakout spaces and allowing workers to rest, or even nap, during the course of a working day. Such practices are not, however, widespread. In such contexts, a dedicated space, with a digital intervention which is of a short and fixed duration, and which is actively sought out by the user, would be appropriate. In any situation where a person has a stay of any duration, or where they return on a daily basis, such as the workplace, more complex approaches become necessary. In a long-term residential context, this might be answered by an ambient intervention which has the capacity for subtle and sustained variation, in order to avoid a user becoming bored with the content. Such an intervention also has the potential capacity to deliver long-term impacts on affect and personal wellbeing.

The daily round of the elderly person in a residential setting is different to that of the workplace. It does not include “work” in the conventional sense, but does include the need to complete a variety of cognitive tasks, many of which, including routine activities of daily living, become increasingly challenging though cognitive impairment, often accompanied by physical impairment. Design of the physical environment to maximise usability, including through integration of response geared to meet functional need has been discussed, as has inclusion of architectural characteristics known to promote wellbeing. In keeping with a dual approach that also maximises psychosocial congruence, sensing, combined with ambient technologies, facilitates a more overt and targeted intervention, other versions of which might serve in various architectural contexts where a restorative environment stands to make a contribution to well-being.

In the general sense, the intervention should aim both to de-stress the user and to restore the capacity for directed attention, in order to support cognitive function. This should in turn have the effect of enabling more successful interaction with the environment, whatever the context. Desirable outcomes might vary somewhat between contexts: for example, in a workplace setting, the opportunity for restoration might support better completion of tasks, or sustained input. For a person with dementia, emphasis might be placed on active alleviation of stress, at

the same time as allowing attentional restoration and conservation of cognitive capacity. This is reflected in the overall MyRoom model: while congruence is supported functionally by spatial design and assistive/prosthetic technologies as far as possible, the model also integrates a digital/multimedia environmental intervention designed to de-stress and facilitate attentional restoration. It is intended to be supplementary, and complementary to features of the built environment which support wellbeing, but which may not always be accessible or available to the user, for reasons previously discussed.

Stephen Kaplan proposes what might be described as a dual approach to restoring directed attention (Kaplan, 2001): that, firstly, it should be conserved, and such mental effort not unnecessarily expended, in addition to allowing for restoration. He refers to two “mandates” necessary to achieve the sort of attentional restoration which has been traditionally achieved through meditation, which, of its nature, requires training and skill, attained by practice. He emphasises that, by contrast, other restorative experiences, such as can be achieved from nature, must of necessity be achieved by different means. Achieving restoration by some alternative means seems a particularly appropriate approach to adopt when catering for the needs of a user who is cognitively impaired, including due to dementia, and thus may no longer be in a position to learn, or only to learn in a limited fashion. It is equally so for the patient in an acute hospital setting. In the former case, cognitive impairment may also make it difficult or impossible to remember to engage in regular practice. In the latter, the impracticability of learning while undergoing surgery or during an acute illness is obvious, while the benefits of being able to actively counteract the effects of stress are equally obvious. In either of these scenarios, the aim must be to bring the user to a meditative, or similar, state passively, without her active involvement in bringing it about, as she may not be capable, by circumstance, of such involvement. With regard to long-term patients or residents, it is notable that, while improvements in performance on cognitive tasks were noted after regular practice of relaxation techniques in a workplace situation, regular and more frequent practice in

achieving restoration was required in order to produce positive changes in affect.

(Peters, R. K., Benson, H., Poter, D., 1977)

Kaplan's first mandate is to avoid calling on tired cognitive patterns; this is related to the sense of "being away" from normal concerns. So, any intervention which aims at restoration must avoid the need for further directed attention, and associated inhibition of other thought processes, in order not cause further mental fatigue. This suggests, in healthcare contexts especially, an intervention which is passively activated. In certain contexts, actuation in response to sensed affect might be appropriate, as is one which operates at a background or peripheral level until required, and then becomes more overt. Kaplan's second mandate is that in order to achieve attentional restoration, the subject should avoid unnecessary (mental) effort, and relates to the remaining three properties of restorative environments, i.e. *fascination*, *extent* and *compatibility*.

The most immediate conclusion, from the review, is that any restorative visual intervention must incorporate natural imagery, or imagery derived from natural and fractal patterns, to provide "soft fascination". In order to command involuntary attention, the intervention will need to hold the user's interest, but without conscious effort. Images might be digitally manipulated or animated to allow for constant but subtle change, for example, by zooming, fading or panning between images, rather than using static images; a further possibility is use of film or video footage. The use of animated images allows the designer or creator fine control over the content, and permits the introduction of elements such as rhythm, theme and variation, almost in the manner of a piece of music, but in a visual format. Hans op de Beek's "Extensions", which is composed of animated drawings, possesses some of these qualities (op de Beek, 2009). The scale at which the visual content is presented in the room is also considered significant in order to create a sense of "being away", by contributing to "extent". While the intention is not to provide immersivity in the sense of a virtual reality environment, the intervention should nonetheless be made at or near the scale of the room, i.e. occupying a considerable proportion of a single wall surface, so that it tends to fill the participant's field of vision from a chosen viewpoint. The viewpoint might be a comfortable chair, or opposite the bedhead in the case of a user who is completely bedbound. "Extent"

is also enhanced by creating, in the restorative environment, a sense of connection with the user's own experience, and the greater world (Stevens, 2010). These aspects are all specifically addressed in the proposal.

In a scenario where the room occupant is cognitively and/or physically impaired, the suggestion is that visual intervention might operate within the BMS as an application actuated automatically, including by system response to real-time bio-sensing indicative of patterns of affect, and specifically, indications of inappropriate stress levels. At the same time, with continuous real-time sensing, the system for each individual room might be programmed to "learn" from such patterns, which will then be reflected in how and when the response, in visual and other forms, takes place. Thus architecture can be enabled to respond overtly to patterns of affect and behaviour. Where response is managed by affect, those patterns become overt, and continuously manifest in the aesthetic changes actuated within the room environment, making explicit the constant transaction between person and environment.

Chapter 2 refers to the capacity for real-time aesthetic variability in adaptive architecture, where colour of facades, or lighting, is varied in response to activity, and the visualisation of that response is moderated by considered design intervention. Continuous aesthetic variation in response to context is also present in kinetic facades. It is not much of a stretch to imagine similar interior interventions based on sensing of the person, rather than context, and in particular of ongoing affective state. MyRoom proposes a personalised approach to achieving sensory variability in the very particular context of one's own life-space, where personalisation through affective response and selection of imagery becomes feasible, in a manner not possible, or appropriate to, more public domains. In an isolated situation, actuating a response might simply involve an application being switched on as a once-off event. The prototype was simplified out of necessity, given the early stage of the research, and involves simple actuation of a single application. In a real-life scenario, the visual application will co-exist with multiple applications, orchestrated by a room management system. System inputs will be

from multiple embedded sensors, which acquire data relating both to context (internal and in some cases, external) and user. The system will be required to interpret and manage inputs, and to use interpreted data to manage actuation of multiple applications, often simultaneously. For example, any visual intervention will take place as part of a managed dynamic lighting system. As described earlier, actuation of specific light-fittings may be contextualised in data relating to user activity. In such a real-life scenario, bio-data indicative of affect will also need to be contextualised within environmental data, which models user position, movement, and so on, so as not to mistake, for example, an increased HR brought about by physical activity, for an increase in HR resulting from arousal. To achieve accuracy of interpretation of affect, it is likely that multimodal sensing will be required, or alternative and newer means of sensing affect, including video tracking of facial expression and movement, for example. Desktop applications for tracking affect are already available, but still require conscious user input and self-monitoring, largely impracticable where a user is severely cognitively-impaired. What is proposed here consists of a largely closed environmental feedback loop, where affect is sensed and contextualised through architecturally-embedded sensing, supplemented by wearables only if absolutely necessary, and where feedback is expressed in terms of environmental response, which in turn operates on the user. At the same time, there is the possibility that where affect is overtly reflected in environmental change, that a user may gain some awareness of her own state. In other possible applications for non-impaired users, this might be valuable as a visualised and accessible form of biofeedback therapy. There has been some success with use of bio-feedback for people with early-stage dementia. Light stimulation of various sorts, including 1072nm infra-red light, has been tested; clinical trials are ongoing for the latter. (Fukomoto, 2013) (Quietmind Foundation, 2010). The latter uses a helmet apparatus, which may be manifestly unsuitable for persons in the later stages of dementia. It is suggested that biofeedback and light therapy be environmentally embedded, to reduce unfamiliarity of the technologies and procedure by obviating the necessity for wearable apparatus. Concerns regarding security of personal data in this particular context can be allayed to some degree by the use of a closed loop, where data is unavailable outside the system. Issues of

system security therefore differ significantly in priority from those of internet security of personal data, though some of the same system protocols may be applicable. Sensed bio-data from a therapeutic context is less likely to be of interest or use to an uninvolved third party. Research which tracks affect in workplace situations has already been carried out, in order to determine how it affects performance (Yano K, Lyubomirsky S, Chancellor J, 2012) and may raise far more significant issues of privacy and security than its use in a situation where it is acknowledged that the user is vulnerable, and needs support or care. As always, context, be it physical or psychosocial, and brought together in the built environment, is everything.

The development of a more comprehensive and individualised therapeutic or salutogenic intervention will heavily rely on software in order to generate non-repeating visual content. Two approaches are set out here, the first based on response to user affect, and the second on variation achieved through programming using algorithms based on time-evolving fractals. Eve Sussmann's film "whiteonwhite:algorithmic noir" (Sussmann, 2012) suggests the first possibility for generating non-repeating content: it uses an algorithm romantically entitled the "serendipity machine" to create a film which is unique on every showing, and never follows exactly the same sequence. 3,000 film-clips, 80 voice-overs and 150 pieces of music were grouped, and each group assigned specific meta-tag by the artist. A metatag is a coding tag, and can be informally described as "information about information". The algorithm uses the meta-tag assigned to any particular image to determine from which group of images the subsequent image/clip is randomly selected. While whiteonwhite:algorithmic noir possesses narrative qualities, generated by the artist's assigning of metatags, use of an algorithm to control image sequence would also enable the creation of an abstract, non-repeating film/video piece, which possesses an "aesthetic narrative". In the envisaged restorative intervention, management of image sequences might be based on user preferences for images or clips, established through interpreted sensing. For an elderly person in care, and especially with dementia, material which promotes personal reminiscing could be included. The intervention might thus be designed to

have personalised symbolic meaning, in keeping with Corcoran & Gitlin's principles (Corcoran, Mary, Gitlin, Laura N, 1991). Visual content might, on that basis, include imagery of landscape familiar to person from earlier life, and particularly of whatever topography or places which most strongly correlate with the idea of home for that individual. The incorporation of digitised archival photographic material could also be considered. Place and identity are often inextricably interlinked in memory. In an Irish context, the meaning of the word of "*dúchas*" embraces both "heritage" and "local place", as well as ideas of belonging and identity. Detailed descriptions of place, and local topography, are a common theme in Irish literature and poetry. The relevance to this proposal is in the possibility of a personal evocation of place as an aspect of the visual intervention. In this fashion, the concept of personal place might be extended in the present moment beyond the boundaries of the room itself. The intervention might also, through conveying the required sense of "being away", necessary for restoration, reflexively also convey the opposite sense, of "returning" to the present moment, through incorporation of some sort of visual narrative. This may be of particular benefit as compensation for immobility or physical confinement.

Initial image preferences might be established through user and carer interviews, curated by an artist or videographer, and then sorted and manipulated, with creative input. The efficacy of such an intervention can be gauged by qualitative analysis, for the present, in the absence of suitable unobtrusive sensing methods. In the future, the reaction of the user, including preferences for specific images and sequences, might be identified through direct sensing of user affect, interpreted by machine learning. The system could then be programmed to prioritise specific images or sequences, based on sensed user preference. Imagery that generates a significant positive response would therefore recur most frequently. In the same manner, images could be "retired" or downgraded in terms of frequency if they became ineffective through over-exposure. Use of bio-sensing technologies, coupled with machine learning, can thus facilitate the making of what is effectively a constantly-evolving and personalised artwork. Editing and extensive manipulation of images would have been either unwieldy or previously impracticable in the

absence of digital techniques. Further possibilities exist for incorporating user interaction with the installation, for example, through gestural interfaces, which thus contribute to reinforcing a sense of self through action on the environmental interface being met with a visible reaction. Eye-gaze technologies suggest other types of interaction: for example, in order generate a zoom into a particular area if the user's gaze lingers on it. Whether such features prove beneficial for this user group will be a matter of trial and error. The desired end of attentional restoration might well be achieved by completely passive viewing, allowing as it does time for daydreaming, in support of maintaining self-identity.

A further proposal for generating continuous digital visual content involves use of fractal patterns, not only as an intrinsic element of natural imagery, but in alternative approaches to programming the ongoing variability of the visual intervention. "Time evolving-fractals" are characteristic of much musical form; it is possible, for example, to predict mathematically the pitch of the next note in a sequence, though not when it will occur. Both pitch and rhythm in Western music follow a $1/f$ distribution (Levitin, D J, Chordia, P, Menon, V, 2012), also seen in the frequency of occurrence of natural and sensory phenomena. While most conventional visual art forms cannot be said to possess any time-evolving properties (other perhaps the possibility of multiple viewpoints, which are external to the work itself), use of animation and/or video footage, facilitated by digital manipulation and programming, and using fractal algorithms to moderate temporal variation, allows for this fascinating possibility. Attempts to describe music and colour analogously originate as far back as Pythagoras, who also set out the mathematical structures which still form the basis of Western musical form. A number of composers and artists, notably Kandinsky, have experimented with visual representations of music; many of these were synaesthetes, that is, capable of simultaneously experiencing a sensation through more than one sense, for example, seeing colour or shape on hearing music. There is the further possibility that there are synaesthetic associations between architectural form and sound, or colour. Visual representation of music, or the application of musical structure to visual imagery, as proposed here, is referred to as "visual music", a term coined by

the art critic Roger Fry with reference to Kandinsky's work, or "colour music". Future research might ideally include creation of non-repeating, continuous ambient video content, based on animated stills and/or video footage of natural images, where variation is moderated by algorithms based on time-evolving fractals. The intervention will not set out to model itself on a specific piece of music, or "translate" it into a visual piece, but will rather treat images and pattern in a manner which evolves over time, so that the visual experience is dynamic and continues to engage, combining the elements of both predictability and surprise, analogous to those found in Western music. Music has been repeatedly demonstrated by research to be therapeutic, and successful in reducing stress in real-life situations. Other researchers/performers are using sensing of emotion in the making of musical performance (Knapp R. B., Lyon, E., 2011), and also creating "intermedia", where music is used to generate simultaneous visual content. In both cases, the creative approach is entirely dependent on imaginative use of ICT. In addition to the tentative precedents for installations made at the scale of the building referred to in Chapter 2, there has been considerable exploration of sensor-driven interactive visual art, created in response to physiological data. (Edmonds, E., et al, 2004) The prior existence of such formats in other art forms suggests their appropriate translation to architecture, as in this proposal.

Some academic commentary based on research into fractal aesthetics takes a very narrow, and largely uninformed view, of how contemporary architecture might usefully incorporate fractal characteristics for the purpose of promoting well-being, effectively excluding much of the architecture of the 20th and 21st century by its narrow criteria, in favour of literal interpretations such as fenestration which apes the forms of branches, and so on. This is likely to be a reflection only of an author's personal preference with regard to architectural style. Comment by R.P. Taylor takes a broader view of the possibilities available, and is clear and analytical, without excluding any possibilities. (Taylor, 2006) As we have seen, architectural design remains connected inextricably with the natural; rather than it being the case that ICT and sophisticated engineering technologies preclude inspiration from, and reference to natural form, they actually facilitate a move towards an

architecture which into which the intrinsic qualities of the natural world are inextricably bound on an ongoing and transactional basis. Even the structure of the intelligent networks required to drive such response are themselves derived from natural systems (Henderson, 2007). Taylor's comments in relation to internal environments are very pertinent, and encouraging, in that they also refer to the need to avoid calling on fatigued cognitive patterns, together with the suggestion that variation be provided by use of "evolving lighting conditions" and "electronic screens", both of which are key components of the overall MyRoom proposal. Taylor's reference to the real-life example of staring into flames, or moving branches as sources of "fractal stress relaxation" are interesting in the context of a decision to base this proposal on a visual intervention, precisely in order to emulate such continuous visual variation. The possibility of creating a non-repeating video piece where that change is mediated by a logarithm derived from fractal patterns is in itself an intriguing proposition, as is the possibility that both content and repetition of imagery might be moderated in a very direct way by user reaction. The issues Taylor raises about individual preferences for certain types of fractals might be answered through learning from sensed data whether certain images, or types of imagery, are more effective. Where the visual intervention is actuated in response to sensed affect, no conscious effort, requiring directed attention, is involved on the part of the user in initiating it. The use of natural imagery, known to assist restoration, presented in a constantly-changing fashion, in order to engage and hold involuntary attention, and the scale of the intervention, together act to fulfil the requirements of both mandates and aim to create "another world" within the user's personal life-space.

In a real-life scenario, it is envisaged that a room sensor network, possibly operating in conjunction with a body sensor network, will continually sense an individual user's bio-signals in a context-aware fashion. Contextual awareness implies monitoring of both activity and the environmental context. Some of this data may also be used simultaneously to regulate other environmental characteristics, for example, temperature, or lighting levels. System and/or sensor intelligence will, of necessity, play an important role in developing a coherent integrated model.

Distributed intelligence within the system is an essential prerequisite, as is an emergent or dynamical system architecture. Multi-modal sensing may be required in order correctly identify affect; for example, to distinguish an increase in heart-rate (if it is being used as a marker) caused by increased physical activity to an increase arising from emotional stress. Some such bio-data will also be of use in tracking medical status; numerous mobile 'phone applications for such purposes have become available in recent years. One of the functions of system intelligence will be to continuously filter out irrelevant information, at local level. On-board sensor processing can be designed to observe change in status, or changes in pattern, contextualised within the room and subject conditions at the time, and only communicate significant information to other parts of the system. A simple example is this: the system does not need to react if the person's HR increases while, for example, watching the Grand National on TV. It may need to do so if the increased HR arises from frustration in performing a task where actuation of an application might make the task easier, or even to note that an object of interaction is a source of frustration, as an indication that redesign might be necessary. It does, however, need to be aware on a constant basis of the user's activities, and to be able to arrive, through processing of sensed data, at an approximation of what those activities are. Another example: a person walking across the room is not a cause for alarm. A person pacing from frustration is. A person who is unmoving and in a standing position may pose an issue that a static seated person does not, as the former may be an indication of confusion in a person with dementia. System interpretation of user status might be assisted by overt carer input at the set-up stages, that is, through directed coaching of the machine-learning capacity of the system. This may prove singularly appropriate in the case of a user who is not capable of making such conscious inputs herself. In other scenarios, where a user is not cognitively-impaired, (s)he might simply be able to directly communicate status to system in response to an overt query generated by the system. (for example: "are you trying to switch on the desk-lamp?") However, if this had to be carried out for every minute action it might become tiresome even at set-up stage; thus some basic parameters for activity should be established in a lab situation prior to testing in a live environment. Alternatively, novel sensing methods, such as inference of

affect from real-time analysis of facial expression, might provide reliable information. In a residential care scenario it will be possible to build up, over time, a picture of an individual's daily and longer-terms patterns of activity and affect, both positive and negative. Where daily peaks in stress, such as those associated with "catastrophic events" are observed, this data might be used to anticipate the possibility of such an outburst, and to respond by actuating de-stressing interventions in a timely fashion. In addition, intervention on a daily basis over a longer time-frame offers the possibility of fostering a general improvement in well-being and affective status.

The ability to sense stress in a context-aware manner also permits use of the system as a design evaluation tool, by facilitating identification of sources of stress which might arise through incompatibility between a user's abilities and environmental affordance, especially as ability diminishes. Such a system might conceivably be used in other designed contexts to elicit information about the effects of design, and of specific design interventions in the built environment, on affect, both in the short and long term. This approach is of particular value in a scenario where a vulnerable end-user cannot be interviewed or surveyed for research in the conventional fashion, because of cognitive or other impairment, or illness, and may yield an invaluable insight as to how such users truly experience and interact with their surroundings. Information acquired through a carer inevitably includes the possibility of its being compromised though being filtered by the interpreter's own views.

The route to the realisation of a full working prototype must if progress through iterative research with differing user groups, starting with healthy subjects who present fewer challenges, especially from the perspective of aesthetics. The aim is to first establish benefits to healthy subjects, then test with other user groups, without need to artificially induce stress, since it can reasonably be presumed that a person with dementia experiences higher levels of stress than a healthy subject, and on an ongoing basis.

MAKING IT REAL

As ever, the foremost requirement for the creation a genuinely congruent room environment is that of sufficient physical space in the room, required in this case to accommodate a large-scale display, and also to permit the user a discrete space for restoration. For palliative care, this may no longer be feasible, and the intervention may have to be limited, or usable from the area in immediate proximity to the user. Developments in screen and display technologies open up the possibility of screens at room scale. While several such technologies are already available, at a price, in the form of large-scale glass LED screens, and specialised film which can transform any area of glass into a screen, research is also investigating alternative means of delivery of visual content, in the form of e-paper, and LED textile, which may prove especially promising. Textile is more pleasant in aesthetic terms than any hard surface: it possesses softer tactile qualities, often lacking in healthcare settings, and can absorb some sound. Currently, the display resolution of LED textile is very low, though when used with imagery that takes account of this, the soft focus can contribute to the aesthetic qualities of the viewer's experience, lending images an almost dreamlike quality. LED textile is also limited at present in terms of available size and physical format, as well as there being issues of durability in certain architectural contexts, healthcare in particular being notoriously demanding in terms of specification.

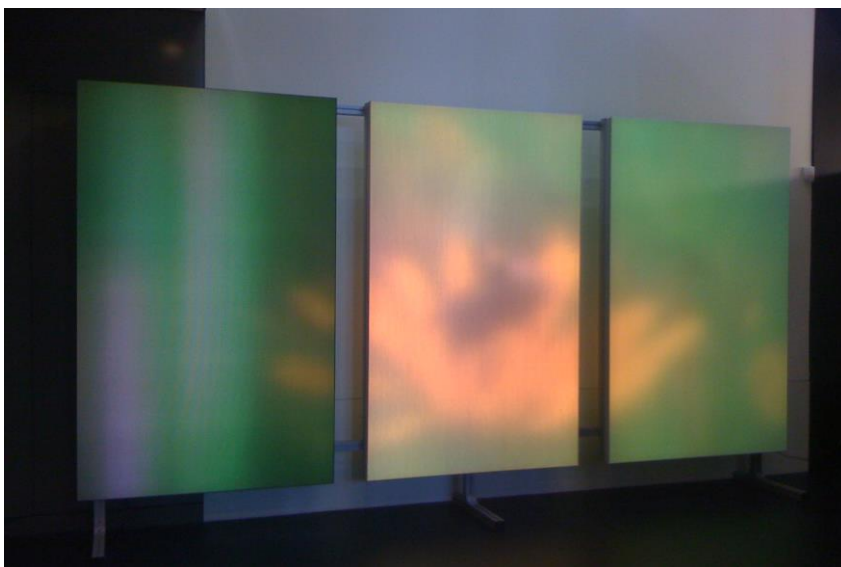


Fig. 6.2 Philips Lumalive ® LED textile display

LED textile and other screen technologies may also offer additional therapeutic potential, as they utilise transmitted light, rather than the projected images of the prototype. Light therapy might then be delivered unobtrusively through the medium of embedded visual content, rather than via a specific therapeutic device, such as a bright-light or blue-light fitting. At the same time, Architects-of-Air's Miracoco luminaire (Architects-of-air, 2011), a temporary inflatable structure, seems to possess calming and therapeutic properties even though colour in this case results from filtering of light through coloured plastic. The user's experience of colour is completely immersive.



Fig. 6.3 Miracoco (Architects of Air, 2011)

MyRoom Demonstrator

A very simple prototype of a visual intervention actuated by sensing of affect was made and tested during the course of the PhD research. The purpose of the prototype was two-fold: firstly, it demonstrates that real-time environmental change, in this case, changes in the visual aspects of a personal space, can be elicited in response to bio-sensing which is indicative of psychological affect. Actuation takes place in response to a specified personal stress threshold being breached. Secondly, it hopes to reinforce existing, though preliminary research by Wyse and others, which demonstrates the efficacy of natural and fractal images in

performance stress relief (Wise J A, Rosenberg E, 1986). Responses observed in previous experiments (that is, recovery from artificially-induced cognitive stress) were achieved rapidly, and in response to single static images (Saito Y, 2007). This experiment offers the possibility of exploring these responses over a longer period of time, and examining whether there is an increase or decrease in efficacy. Does the de-stressing response become fatigued, and if so, at what point?

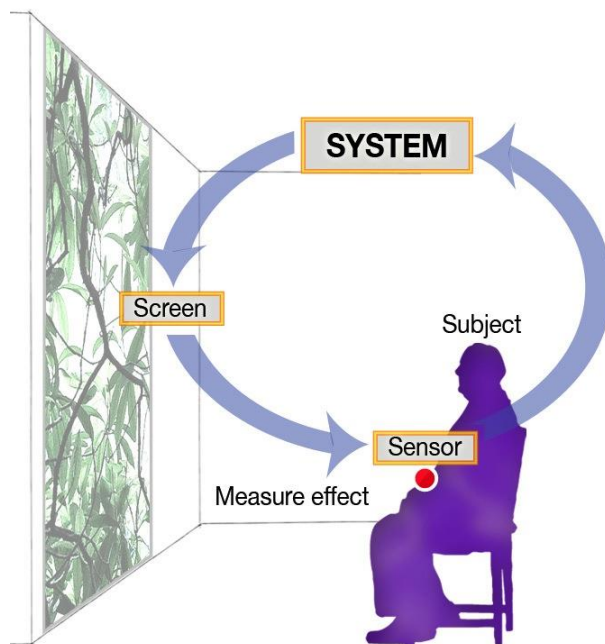


Fig. 6.4 *MyRoom partial prototype: diagram*

For the MyRoom prototype, made and tested during the course of the PhD research, with collaboration from the School of Applied Psychology in UCC, and with limited technical support, actuation of video content is achieved in response to sensing of user affect, as measure by real-time sensing of heart-rate (HR) and Galvanic Skin Response (GSR), which are standard indicators of stress arousal. Previous research by others has relied on very short exposure to static images of natural scenes. The prototype, while rudimentary, might thus be regarded as a preliminary exploration of the effects on stressed states of more extended exposure to visual stimulus based on natural images, in an architectural context. For the prototype, images were projected onto a stretched blank canvas, creating the impression of a constantly-changing picture. A short video piece consisting of

animated natural images was prepared. Creative input was limited, though almost any decision can be considered a design decision. The very act of framing a shot for a photograph involves an aesthetic judgment on the part of the photographer. At the same time, if notions of beauty cannot be divorced from notions of functionality, this is never more so than where natural images are concerned. Therefore, though aesthetic input was minimalized, insofar as it possible for any designer to do so, inevitable aesthetic choices were made also in the selection of images, and in their sequencing. An interesting outcome of simply grouping images approximately by colour, starting with blue-greens and progressing through warmer tones to darker blues and finally reds coincided very closely with the times of day at which photographs were taken, and ultimately lent some coherence and an "aesthetic narrative" to the sequence. Types of image (clouds, waves, vegetation) also suggested a means by which to link successive images. The images were not otherwise digitally manipulated or animated, except to pan, zoom or fade between images. In the partial prototype, continuous real-time bio-sensing is processed and used to actuate environmental change, in the form of the video piece, incorporated at a scale relating to that of the room, rather than to a personal interface such as a laptop screen. This is so that the experience becomes immersive. The interaction loop is closed by the effect on the subject/viewer's affective state as measured by HR and GSR, as proxies of psychological stress. Actuation of the video piece was achieved through processing of the HR signals. Participants in trials were asked to carry out a selection of tasks, designed to induce cognitive stress, including a mathematical task and a spatial task, and to watch a video, while in a seated position. This method of stress reduction replaced initial use of a standard Stroop test, which failed to cause an increase in stress in a number of designers tested as the first subjects. The rise in heart-rate triggered by the increase in stress was used to actuate the video piece, when a percentage HR threshold had been breached for a specific period of time (two minutes). The HR signals were transmitted from a chest-strap monitor via Shimmer unit to a computer, which actuated the video in response to an increase in HR being observed for a continuous period of one minute. The observer's affective reaction to the video piece was then monitored by observing the effect on the subject's heart rate over the duration of the video

piece. The process served as a nice illustration, for an architect, of what real-world prototyping involves, and a window into the world of the other disciplines which would be required to collaborate in the making of responsive architecture. Progress was dogged by innumerable minor technical issues, requiring the procedure to be run many times in order to refine it, so that it would work seamlessly and dependably. Even such a limited exercise involved wireless communication using different frequencies and devices. The HR sensor communicated with the Shimmer unit on a 5GHz frequency, while the data was ported to the laptop via a Bluetooth connection. While it was the intention to use wireless communication between the laptop and the screen, this again proved to be a relatively new-to-market technology, and was dropped, as it was of little benefit to an experiment being run in a fixed location, though it would have enabled the entire model to operate wirelessly. Initial trials did indicate a lowering of stress in a number of subjects, to just below the baseline level established though sensing, where it remained until the end of the video piece. One participant, who did not show bio-signals consistent with de-stressing, did however comment that the effect of viewing the video was to allow his mind to associate freely, leading to reminiscing. This effect, if replicable, is of interest with regard to people with dementia. In some subjects, de-stressing reactions to specific images in the sequence was observed. The demonstrator and pilot tests are described in more detail in Appendix 1, *MyRoom Demonstrator and Pilot Tests*.



Fig. 6.5 *MyRoom demonstrator*

Comment

Further steps towards the realisation of an integrated responsive environment will require a considerable amount of collaborative interdisciplinary research, in order to explore, singly and collectively, the various anticipated interactions between a user and her context, where the means of interaction is embedded in the physical context. Though the thesis model concerns itself with personal space in a care setting, the same issues and practicalities are relevant to a contextualised model for a user in a home setting. There, the agenda differs somewhat, in that the aim of most such technological interventions is to delay admission to care. However, the overall intention in either scenario remains the enhancement of quality-of-life through, the two-pronged approach of increased/extended usability together with promotion of positive affect. Ultimately, what should be sought is the passive promotion of what Herbert Benson describes as the “Relaxation Response” (Benson, 1982), which has measurable physiological correlates of slower heart-rate and respiration, lowered blood pressure, decreased metabolic rate and characteristic changes in brainwave patterns. While these might best be measured by EEG, it would not be possible to use this measure other than at the prototyping stage with healthy subjects, extending possibly to subjects with early-stage dementia.

Issues of user, context, and activity will resurface again and again in the making of responsive architecture: it is the understanding of the interaction or set of interactions which is quintessential to the design of the overall responsive system. In this manner, the architect revisits in a novel fashion the concerns of Gropius (Gropius, 1962) and Neutra regarding the precise nature of the intimate interaction between architecture and the person. A criticism which frequently recurs at the present time is that architects, in ever more strenuous attempts to design “iconic” buildings, have done so through an almost exclusive focus on the external, on the superficial, too often to the exclusion of any great consideration of the individual end-user. The experience of the passer-by on the street, or the “first impression” are frequently prioritised at the expense of the more thoughtful, detailed and longer-term experience. Context, of course, plays a role: for certain typologies,

statement-making may be more appropriate than other. For a majority of buildings, there is a strong case for what Malcolm McCullough terms “a quiet architecture” (McCullough, 2004), which unobtrusively and competently goes about its business of aspiring to make better places for people to live and work. It remains a matter of surprise and disappointment, that even in healthcare architecture, those buildings cited as exemplars still often display the same failing: a “user-friendly” and architecturally impressive entrance space is provided, while wards are still designed built as the same barren cells they were half-a-century ago. A notable and encouraging exception to this is the new Royal Children’s Hospital, in Melbourne, where the treatment of individual patient rooms displays every bit as much concentration of thought and effort as the principal spaces and overall design, and where design, and detailed design, is integral to the outcome, rather than consisting of a superficial nod towards a “child-pleasing” aesthetic. However, it remains one of the few examples of its kind. Embedded systems, including for visual content and therapeutic applications, offer the opportunity to retrospectively address design deficiencies in existing buildings, through enhancing ongoing user experience. They can offer an aesthetic overlay to the overly utilitarian and the purely functional, as encountered too often in existing healthcare design. Where the designer has left an empty box, devoid of any detail, or design intent, embedded applications, such as that described, can fill a space with continuous interaction, ever-changing and personalised. The embedment of sensing and actuation allows a person’s own room to become “multisensory” in a personalised fashion, rather than a situation where a specific room is provided for all users.

Reference must be made here to current research and development by Richard Mazuch (Nightingale Associates) of hPods, or healing pods, which deliver targeted multisensory intervention (including colour, images, sound and aroma) for a variety of illnesses and conditions, in a small sealed cabin in which the user sits for the duration of the therapy. The approach is suited to more acute or short-term interventions. MyRoom takes an alternative approach geared towards long-term care and salutogenesis, where multi-sensory elements become an integral part of architectural context, enabled through sensing to respond to changing user needs.

While a visual intervention has been described here in some detail, the same technological means can be used for actuation of other sensory inputs, in pursuit of enabling multisensory responsivity. At the same time, real-time management of interaction through affect feeds out own feelings and sensations back into our “sensible world”, which has physical form in our surroundings. In an affective responsive architecture, the “microfacts” Neutra describes as being “*recorded and stored*” (Neutra, 1954) by the nervous system are captured and projected back into the architectural environment. As such, responsive architecture, and specifically, architecture that were response to the person is intrinsic, finally satisfies Eco’s definition of the “Open Work”. Through the introduction of embedded sensing and response, the aesthetic outcome becomes a never-ending dance in which actions and reactions of user or users form an implicit component, and where that outcome reflects the patterns of usage, experience and perception, translated into sensory response through the medium of ICT.



Fig. 6.6 Images from *MyRoom* video

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Chapter 7

- **Limitations of the research**
- **Conclusions**
- **Further research**

Limitations of the research

In the case of design research, outputs often include the production of an artefact; in architectural research one might expect a model, a design, perhaps a full working prototype of a component. In this thesis, the output is largely written, consisting of a description of a new paradigm for responsive architecture, and a detailed description of related design proposals.

The limitations imposed by the constraints of individual research at doctoral level, including restrictions of funding and on substantial collaboration, imply that it was not possible to construct a full working prototype. Instead the thesis has taken the direction of describing a theoretical design model which might form the basis of a built full prototype in further research, should funding and collaboration be achieved in future. Such an outcome will require intensive long-term collaboration between the designer and a number of ICT disciplines. Creation of non-repeating visual content, as described in Chapter 6, constitutes a substantial piece of research in itself. To design, prototype and fabricate an entire intelligent responsive environment, even at the scale of a single room, requires substantial inputs from researchers in a number of areas, with extensive collaboration. The research and development of an entire room and its management system will require a dedicated collaborative multi-disciplinary research programme, taking place over a number of years, with substantial financial investment, which more than likely will need to be sourced through industry. So, for the moment, an affective responsive environment, which is intended to promote salutogenesis through maximising

congruence, by managed real-time response to the person, remains a tantalising possibility which will take many years, and many researchers, to make a reality. That does not undermine either the novelty of the concept, or its potential significance in terms of how we make better environments for humans in the near future. Once the possibility comes into being that buildings might quite literally respond to how users feel, the idea is impossible to ignore. In the meantime, the thesis explores in some detail the concept of affective response in architecture: why it might be sought, where it might be most appropriate, and where the architect, as much as the software writer, or systems designer, might begin. The experimental prototype is a tiny step in that direction. To test the concept thoroughly will require much design iteration: of video content, of sensors, of software, and so on. Many research outputs across the field of ICT are moving currently in the direction of technologies which lend themselves to integration into such an environment, but only if reworked and integrated into an overall schema. At the same time, MyRoom must always be perceived as a coherent entity, rather than a mere assembly of parts. It is in maintaining this coherence, going forward, that design input must play a major role, in the same way that creative input (for want of a better term) and abductive reasoning led to the novel concept of an affective responsive environment.

CONCLUSIONS

In the manner of design projects in general, a critical analysis of the information to hand, in this case the literature review, has given rise to a series of design proposals, in direct response to the brief requirements of the NEMBES scholarship, which was to investigate the use of wireless sensor networks in environments for elderly people. The succinct, though somewhat unexpected answer to the research question “How can embedded technologies be utilised to maximise the adaptive and therapeutic aspects of an own-room long-stay healthcare environment for an elderly population?” is simply: “by making responsive architecture” or more specifically “by making responsive architecture which responds to affect”. Part of the thesis becomes, as a result, a discussion on this specific and novel type of responsive architecture. That paradigm presented itself as a design solution to the particular needs of the individual at the centre of the model, an elderly person with cognitive impairment resulting from dementia, with diminished, and diminishing capacity to deal with environmental press. Responsive architecture is then framed, inevitably, as interaction design, always governed by the trinity of person, context and activity. From the examination of the concept of affective responsive architecture at various scales, and the specific proposals made, the following generalisations may be extrapolated:

In responsive architecture, interaction design is redrawn as architecture/ architecture is redrawn as interaction design

The first conclusion arrived at is that wireless sensor networks can be deployed in order to facilitate human interaction with the built environment, that is, to facilitate making responsive architecture, where an entire space, or building, becomes the user interface. As such, responsivity extends the existing capacity of architecture as a setting for human action within the built environment, and interaction with the built environment. Responsive architecture enabled by real-time sensing, and thereby enabling continuously evolving response, creates the potential for ongoing

adaptation managed by conscious design intent, endowing architectural design with an active temporal dimension.

Functionality is reframed, through the lens of interaction design, as usability

The nature of responsive architecture will vary, as does interaction design, depending on context, user and function/activity, in the manner in which architectural design outcomes have always varied. At its best it will comprehensively address ease-of-use, implying both functional and psychosocial fit, and by the same means, also satisfy aesthetic considerations in a manner particular to context, user, and use. Functionality is re-framed as usability, and thus embodies all three Vitruvian principles of commodity, firmness, and delight, when it is accepted that the notion of “emotional design” (Norman, 2004) is an essential aspect of usability. The inclusion of affect in system management affords continuous feedback with regard to user reaction to environmental stimuli, and interaction with the environment, from which the system may be designed to learn.

The significance of context, user and use in interaction design implies multiple scenarios and design solutions for responsive architecture

The range of design outcomes for responsive architecture is contingent, as for any aspect of any architectural design, on context. For environmentally embedded interaction, context has the same meaning in both architecture and ICT, that is, it implies a particular physical locale. However, in the case of interaction design redrawn as architecture, the characteristics of the user(s) are of equal significance, as is the set of desired or anticipated interactions which architectural responsiveness seeks to support. Scale, as an aspect of architectural context, produces possible scenarios which range from detailed interface design in the personal space of an individual, to the collective, and collectively interpreted interactions of a group of people with a building, space, or sequence of spaces. While the range of possible

outcomes is potentially infinite, typical approaches to certain context-user relationships may emerge over time, as new architectural typologies. Responsive architecture also allows the possibility of offering varying solutions to problems which only become overt through use, or which arise, as in the MyRoom scenario, over the course of time through changes on the part of the user's ability to interpret or interact with the built environment.

Responsive architecture can be designed so that the ongoing transactional relationship between user and architecture is made explicit

In the particular model of an affective responsive architectural scenario described in the thesis, where affect is a critical consideration in managing the nature and pattern of response, the ongoing transaction between user and environment is continuously manifested, in this case visually. John Maeda describes design as “a way of making meaning in an uncertain world by marrying form with content, and content with context”. In the MyRoom scenario, content is literally married with built form through the use of large-scale visual display, while at the same time content and context are united through the manifestation of the ongoing interaction between person and environment, made continuously explicit in management and moderation of visual content.

Intelligent system design is an essential prerequisite for any responsive architecture which intends to support either functional or psychosocial fit

Distributed intelligence within a system is a prerequisite firstly for pervasive or embedded computing. Intelligence and machine-learning capacity within an emergent/dynamical system enable the networked environmental management system (for the room in the MyRoom scenario) to adjust on an ongoing basis to user need and context. The success of any specific intervention or application, or of the environment as a whole, may be measured through sensing of affect, as an indicator of psychosocial fit.

In certain contexts, response to affect becomes an essential component of responsive architectural solutions

Inclusion of affective computing is seen as a necessity in any scenario for responsive architecture which aims to be inclusive or user-centred. Such a paradigm for responsive architecture is seen to be immediately appropriate for a vulnerable user in any care setting. The precise nature of the interplay between the user and the architecture will vary even from one healthcare context to another. Affective environmental response has a role in design for the acute patient in a short- to medium- term accommodation, as much as in the delivery of appropriate solutions for person-centred responsive architecture in long-term term i.e. residential settings, where the cumulative effects of lack of functional and psychosocial congruence can result in stress, and stress-related illness, and thus impact negatively on individual wellbeing. This is most particularly the case for elderly persons with dementia, where the threshold for stress of environmental origin becomes progressively lowered, at the same time as the person becomes progressively less able to communicate the cause of a stressful event or environmental interaction, or to quickly recover cognitively from it. Responsivity can enable environmental intervention appropriate to the progression of dementia, as an aspect of maximising congruence. The inclusion of affect in management of response is essential for a user who is extremely susceptible to environmental stress, and unable to communicate need or frustration at unmet needs.

Iterative prototyping becomes a real-world process in the creation of responsive architecture.

Where responsive architecture is framed as interaction design, solutions will be derived from the same considerations that affect interaction design in other non-architectural contexts: namely, those of user, context and activity. In responsive architecture, context implies the physical or architectural context. While every building of a new design might be considered a prototype, this has been assumed until now to be in the sense that most buildings are built untested: in architecture,

the finished product must often be accepted even with inherent design flaws present from the outset, which only become manifest through use. Design is in itself an iterative process, but buildings do not generally undergo literal prototyping in the same manner as, say, a designed product. They end up as effective prototypes by virtue of the impracticality of real-world prototyping and testing on entire building. Complex components, such as repeating, highly-engineered façade elements, are an obvious exception. The history of architecture is littered with failures of prototypical buildings and systems, for which the only solution may be Frank Lloyd Wright's wry suggestion that the client be advised to "plant vines". Any foray into the world of responsive or adaptive architecture will necessitate a progression on the part of practitioners from design modelling, where iteration of a concept is confined to use of drawings or models, including CAD modelling, to inclusion of real-world prototyping of components and interfaces, in preparation for a realised design.

Systems designed to incorporate intelligent affective response automatically support an iterative approach to the design and ongoing implementation of interaction in architecture

A system capable of delivering continuous real-time adaptation, which takes cognisance of affect, is also capable of being used as a design tool for iterative development of interfaces and interactions. Where the ongoing interaction between person and architectural environment is moderated by an intelligent system utilising real-time sensing and response, and where affect is used to manage and evaluate that response, the first built design might be regarded as kind of prototype, which has been enabled to refine and adjust certain aspects of itself continually in response to patterns of use and need. Problems and their solutions continue to emerge on an ongoing basis. Responsive architecture allows the possibility of offering differing solutions to problems which become overt through use, or which arise over the course of time through changes on the part of the user's ability to interpret or interact with the built environment. In technologically-enabled responsive affective architecture, there exists an unprecedented

opportunity to move on from “machines for living” to “living machines”, centred not only on the user’s functional needs but also on changing affective state.

An affective responsive environment can satisfy the requirements for Inclusive Design

The integration of ongoing adaptivity and responsiveness into architecture points the way towards design solutions, which, by allowing environments to be made adaptable and be personalisable, can satisfy the requirements of Inclusive Design (Coleman, 2006). While the MyRoom proposal is made with a specific user group and its needs in mind, it is potentially usable in many other contexts by all users, with little alteration. Its functionality, usability, desirability and viability as a finished product is dependent on ongoing research, and the precise manner in which such research is structured, i.e. it should always be treated as design research, with a coherent and integrated end-product in mind.

Responsive architecture orchestrated by processed sensing of the person redefines architecture as a fully Open Work

Where sensing of the person becomes a critical consideration in the ongoing management of the transactional relationship between person and built environment, the responsive architecture created becomes a truly Open Work in the sense described by Eco. User interaction, including affect, becomes embodied and manifest in architectural response. The ongoing dialogue between user and environment can be articulated in architecture visually, as in the MyRoom scenario, but also, for example, kinetically, or in a manner that draws on other, or all, senses. The manner in which the transactional relationship between user and environment is expressed through design should reflect the context and purpose.

The symbiotic relationship between architecture and technology is reiterated and extended in relation to sensor-enabled responsive architecture

It would seem that while many of the necessary component technologies required to create an affective responsive environment exist in some form, they are, for real-life practical purposes, embryonic, and do not yet exist in compatible formats that might be used in a properly-integrated fashion, which is where design has its role, whether it be of interface, interaction, or responsive architecture, which must address both. Any future research intended to result in the realisation of a full room prototype will require research and development of its own devices or interfaces, fit-for-purpose for user and context, as well as the research and development of software and intelligent systems. The making of any piece of responsive architecture, and perhaps more particularly, affective responsive architecture, is fundamentally a collaborative and interdisciplinary exercise, where the role of the architect encompasses both that of informed advocate for the user - a technology "gate-keeper" who filters and guides technologies to make them properly usable in the context, and as the real-world designer and integrator of systems and interfaces into a coherent responsive architecture. In the latter case, the architect will work in close collaboration with alongside the engineer and ICT specialist. In this manner the ICT disciplines effectively become yet another extension to the traditional architectural design team. The relationship in this case will need to be especially close. The alternative is a move to middle ground by either the architect or the information technologist, by people akin to the hybrid artist-technologists whom John Maeda refers to in the introduction to "Processing" as "mutations in the academic system" (Reas C, Fry B, 2007). In the professional field, practices like Jason Bruges Studio are at the cutting-edge, but still stand almost alone in terms of what they do. The best outcomes will be achieved where more designers are drawn into the area that overlaps with the technical, and more technologists become aware of the significance of aesthetics in designing technologies and systems that are simple, powerful and elegant. John Maeda cites the significance of design in the development of technological solutions: "Design is the largely implicit aspect of a product or experience that humanizes and empowers a technology or direction

(Maeda, 2013).” In the case of pervasive or ubiquitous computing, where it relates to the built environment, that role is one which the architect must fill. Designers, with their capacity for joined-up thinking, are ideally positioned to imagine a roadmap for the future use of computer technologies in society. In the built environment, in relation to ubiquitous computing, that role should be occupied by the architect, with design as the beacon that illuminates the path.

Responsive environments are well-suited to the needs of ageing individuals with in an ageing society; affective response is particularly well-suited to the person with dementia

Embedded sensing enabling ongoing response in architectural settings provides a means for the feedback loop connecting person and environment to be completed, so that the adjustment of the environment to person, in order to support function and psychosocial congruence, can be enabled, despite increasing impairment on the part of the person, and declining ability on her part to adjust to stressors of environmental origin. This facilitates extending environmental congruence for an elderly person with dementia over a longer period of time. It is particularly suited to meeting the changing needs of the user over the progress of the disease, by reducing stress of environmental origin, and through the capability of responding in answer to changing needs over time. In addition, such an environment has the capacity to provide attentional restoration, and affords a means to communicate user affect externally, in a situation where the user may no longer be able to communicate unmet needs.

The increasing prevalence of dementia suggests that all purpose-built accommodation for older people be designed in future so as to be ultimately suitable for persons with dementia. Dementia is the prime reason for a move to residential care in many cases, while a proportion of elderly people in residential care will go on to develop dementia after they move to a supported residential setting. Responsive architecture, particularly where it includes for management

through affect in order to maximise psychosocial congruence, and reduce environmental press, has the potential to extend individual capacity for independent function, and also increase quality-of life in living with dementia.

Physical environment affects us all, inevitably, through its continual impact on all the senses. The degree of control which an individual has over his/her environment impacts significantly on his/her relationship with environment, and the degree of congruence achievable. The relationship between person and environment is transactional, and subject to constant readjustment, in both directions. Where that adjustment is impeded through cognitive decline, or either permanent or temporary incapacity, stress on the person is an inevitable result, unless compensatory measures are put in place. The same conditions often result in the user being relocated to an unfamiliar and often restrictive environment, either temporarily, or permanently, whether it be a hospital or a residential care setting. The consequences of living long-term in an environment which fails to meet functional and psychosocial needs are arguably more significant than those of being exposed to such an environment for a short space of time, even if the degree of incongruence is less. Given that much available residential care accommodation is still based, in design terms, on what are essentially institutional models, they are very likely to fail to meet the needs of their users. The significance of psychosocial fit and its effect on wellbeing implies that design has a significant role to play in promoting salutogenesis. Evidence-based design, if it results only in a check-list to be ticked off, may prove a dangerous commodity, as it can, in the wrong hands, fail to address the core issues pertinent to good design, which necessarily combines function and “aesthetics” for want of a better term, to maximise usability. Research in the area of EBD, other than from post-occupancy evaluations, often isolates aspects of design and environment. The value of such research, which often ignores the joined-up nature of design thinking, and design outcomes, is sometimes questionable, while at the same time, anything which lends weight to the argument that “design matters” is welcome. The danger lies in assuming that there is ever only one solution to a specific problem: this is anathema to design, and designers.

Further research

Personal preference for immediate follow-up research is the production of suitable non-repeating visual content, as described in Chapter 6. This will require collaboration in relation to programming, and possibly with a visual artist or filmmaker.

Preceded by testing on healthy subjects, such content can then be tested in real-life residential settings, either without sensing, relying on qualitative assessment by carers, or with sensing, should suitable sensors for the user-group become available, or be developed in parallel research in the meantime. Ideally, an unobtrusive embedded sensing solution would be developed in tandem.

If results indicate that a relaxation response is achievable, the application should be tested longitudinally over a period of weeks or months to establish whether there are long-term changes in affect for exposure/therapy that takes place over time. In other possible locales, the means of delivery might vary: for example, it might be appropriate to use with a laptop or pc screen in a workplace environment, or a large-scale screen in a dedicated restoration room. In other healthcare situations, therapeutic content might be actuated at pre-set intervals, or in response to bio-sensing. In an acute care context, many of the bio-signals which are proxies of stress are already being monitored for medical reasons, which might obviate the necessity for additional bespoke sensors.

This research, together with the thesis proposal, might form a prelude to the development of a comprehensive responsive room prototype which addresses issues both of function and psychosocial congruence.

Architecture the Mothership?

The creative possibilities facilitated by integration of sensor networks in architecture, in order to generate response, are almost boundless. There are as many design solutions as there are architects, contexts, and users. At the same time, person-centred solutions can in themselves represent an ongoing interactive creative process.

In plotting a road-map for the future of architecture, and specifically for responsive architecture, it must always be acknowledged that the architectural environment can and does affect users, positively or negatively, unintentionally, or intentionally, and whether or not it operates as it was designed to do. People are in a constant state of interaction with their total environment, including their physical surroundings. Sensor networks have the capacity to moderate those interactions in a nuanced and personalised fashion. Ubiquitous computing and embedded environmental responsivity seem as likely to become a reality in the near future as mobile web technologies have in recent years, as well the pervasive and ubiquitous nature of information that has resulted from their adoption. The ability to moderate ongoing person-environment interaction in such an intimate fashion must appeal to many architects, but in order to be equipped to design for embedded interaction, the education of the contemporary architect must be broadened to include areas such as environmental psychology, system design, and in some cases software design, often considered anathema to a previous generation of architects. The standard-bearers are out there on the horizon; architects have the choice of following on in greater numbers. That may transpire to be less of a choice than a necessity, if they are not lose tenure of parts of their traditional remit, to other design professions, or even to non-designers. In the same way that “accessibility “ has shifted emphasis from an afterthought to design to occupy centre-stage as Universal Design, so it seems desirable that ICT should not be peripheral, or an overlay onto a finished design, but a considered and integrated part of the architecture of the near future. The potential benefits to the end-user can only barely be anticipated at this early juncture. In relation to the novel concept of a personalisable responsive architecture, of which MyRoom is one of an infinite

number possible scenarios, one only needs to look at the current examples of responsive façade design to see how technology is a driver for the creative imagination. Architecture, as the mother of the arts, the vessel, the container for human activity, the person/environment interface, is poised for a paradigm shift in terms how it moderates and influences human action and interaction, as the mothership on the journey to many possible futures.

While the broader research question at the outset might have been: how can architects use sensor technologies in the built environment, by the end of this thesis it has become inverted. How can we not?

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APPENDICES

APPENDIX I

MYROOM DEMONSTRATOR AND PILOT TESTS

Introduction

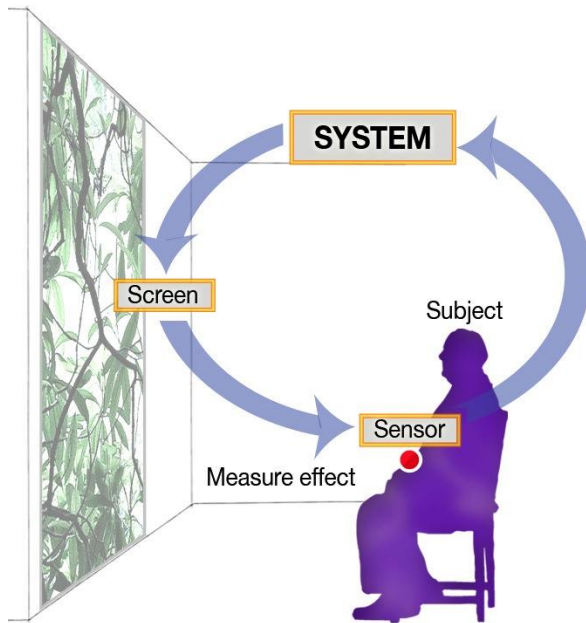
A very simple prototype, which demonstrates user interaction with environment, actuated in direct response to real-time sensing of affect, was constructed as part of the doctoral programme. This was used to pilot an experiment designed to explore user reaction to natural imagery, presented at the scale of the built environment. The same or similar apparatus might be used to gauge the effect of other environmental changes, e.g. colour. The ultimate intention is the delivery of a responsive architectural environment which addresses issues of both functional and psychosocial fit for the user, and in which considerations of user affect by an ICT-enabled environmental management system are seen as necessary to the achievement of user congruence, and usability. The MyRoom model described in the main body of the thesis represents one such possibility.

The demonstrator firstly serves to illustrate the possibility of affective response in the physical environment, acting as a much-simplified representation of a responsive architectural environment enabled by wireless technologies, where responsivity is enabled in reaction to user affect, rather than, for example, ambient environmental conditions. It further demonstrates that *real-time* environmental change can be elicited in response to bio-sensing of an individual, where the bio-signals sensed are a proxy of psychological arousal. In the case of the demonstrator, environmental response, in the form of actuation of video content, is personalised by being actuated in by breach of a specified personal stress threshold on the part of an individual user. In this case, stress response was continuously observed throughout by sensing of heart-rate, as a standard and accepted indicator of stress arousal. Cognitive stress was chosen as a parameter because of its significance in relation to environmental interaction for people with dementia, and the known influence of inappropriate chronic stress on personal wellbeing and health, which is referred to in the literature review in Chapter 1, and again in Chapter 3, with

specific reference to dementia. While the intended end-user is the person with dementia, a decision was made, out of ethical concerns, that any system should be developed and tested for usability on healthy users before broaching the issue of testing on vulnerable subjects in a live setting. The scope of such research suggests that it might be an appropriate for a postdoctoral research programme, which will involve interdisciplinary collaboration.

Objectives

The pilot tests carried out during the course of the research, using the demonstrator apparatus, are a preparation for an experiment aimed to reinforce a small existing body of research by Wise and others (Wise J A, Rosenberg E, 1986), which demonstrates the efficacy of natural and fractal images in stress relief, including responses to single static images of natural scenery (Saito Y., Tada, H., 2007). As the responses observed in previous experiments (recovery from laboratory stress challenges) were achieved rapidly, this experiment offers the possibility of examining observed changes in affect over a time period of 10-15 minutes, in response to exposure to such imagery, and to establish whether the use of video/moving images can produce extended or increased changes in affect. The use of sensing enables impartial observation of user affect. Heart-rate (HR) signals, which are accepted indicators of stressed states, were continuously monitored throughout the pilot experiment in each participant, on an individual basis, and real-time changes indicating stress response were used to actuate a video installation intended to cause a de-stressing response. The prototype, while rudimentary, might thus be regarded as a preliminary exploration of the effects on stressed states of more extended exposure to visual stimulus based on natural images, in an architectural context.



MyRoom Prototype Diagram (UCC Doctoral Showcase 2011)

Equipment Selection

1. Shimmer platform and Polar chest-strap HR sensor.

The Shimmer wireless sensor platform was selected on the basis of 1) cost, and 2) its use of open software, which facilitated writing the software application needed to actuate the video piece. The Shimmer device facilitates transmission of sensed data in real-time, and was used here in conjunction with a Polar chest-strap HR sensor, such as is commonly used in sports applications. A chest-strap sensor using a 5 Ghz wavelength was chosen so as to avoid interference with transmission of data from the Shimmer device to the laptop on a bluetooth frequency. A laptop PC acts as a very simple proxy for a room management system. There was an unresolved supplier issue with boiler-plate software on the Shimmer device, which was transmitting HR in packets of six beats, but this was remedied in the coding used to actuate the video. Other sensors which were considered for use, though easier to manipulate, had proprietary software and overly-restrictive licensing agreements relating to development of applications, and were also considerably more expensive. The wrist-worn Affectiva sensor, which is based on sensing of Galvanic Skin Response (GSR) as a proxy of stress, came on the market during the

course of the PhD programme. However, it was not available with event marking until after the pilot experiment had taken place, and also, HR was considered to be a more reliable measure of arousal. Production of this sensor has subsequently been discontinued. The drawbacks of the Shimmer device included the absence of an on/off switch on the device (now included on the current model), long charging-time, and unresolved issues in relation to porting of data to the laptop via Bluetooth. Whether this was due to loss of contact of the chest-strap, or intermittent Bluetooth transmission was not fully resolved. Reliability of transmission of data would be critical in a real-world application intended to operate continuously in real-time.

2. ShimmerVideo

The ShimmerVideo application, which was written for the purposes for the experiment, actuates a video in direct response to a threshold breach of sensed HR. It was coded to include event marking for baseline heart-rate, generally established over 10 minutes, and for a 10% breach of baseline HR for one minute, indicating a stress response, based on continuous averaging of sensed HR. A third marker was inserted for return to the threshold heart-rate, indicating a de-stressing response in the user. On examination of the pilot results, it was considered that return to baseline HR would have been a more appropriate indicator. HR data files for each individual were exported as.csv files for processing.

3. Projector and canvas screen

A daylight projector and large stretched canvas, creating the impression of a constantly-changing picture, were used to deliver the video content at the scale of the room. A larger-scale and more immersive means of delivery would have been preferable, but was not feasible within the cost constraints which applied to this doctoral research.



MyRoom Demonstrator

4. MyRoom Video

The video piece used for the experiment consisted of a series of unedited images of natural scenes and objects, presented as an extended slideshow of 10-15 minutes' duration. None of the scenes or objects were expected to cause distress. Creative input was limited to selection of images, and sequencing by general image colour. An interesting outcome of simply grouping images approximately by colour, starting with blue-greens and progressing through warmer tones to darker blues, and finally reds, coincided very closely with the times of day at which photographs were taken, and ultimately lent some coherence and an "aesthetic narrative" to the sequence. Types of image (clouds, waves, vegetation) also suggested a means by which to link successive images. The images were not otherwise digitally manipulated or animated, except to pan, zoom or fade between images, giving a limited sense of movement.

Experiment Design

The experiment was designed in collaboration with Dr. Samantha Dockray, School of Applied Psychology, (SoAPs) UCC, and pilot testing carried out with the assistance of postgraduate students from SoAPs, UCC, under the auspices of the

UCC Works scheme. Participants were selected at random from respondents to an email call circulated through UCC email, and ethics approvals applied for, and obtained through the UCC School of Applied Psychology. The documents relating to the ethics approval are appended.

Participants were asked to wear a chest-strap HR monitor, from which the heart-rate (HR) signal was ported to a laptop computer via a Shimmer device. They were first asked to sit quietly over a period of up to 10 minutes in order to establish a consistent resting heart-rate. This value (average resting HR) then served as a baseline, and as the control, as the approach involves testing for intra-individual change over time, and in relation to events that result in a change to cardiovascular activity. As events that may trigger a change in cardiovascular activity include interpersonal interaction, so interaction with researchers was limited in order to minimise the risk of an increase in the level of arousal in the subject, shown as an increase in observed HR. During the baseline phase, participants were asked to fill out forms with basic personal details, and to answer a simple questionnaire in relation to their personal affective state. These questions and measures are not reported to have any impact on cardiovascular activity. A baseline HR was accepted once the continuously averaging HR was stable over one minute. Participants were then asked to complete a number of cognitive and social-evaluative challenges known to evoke a stress response. These included mathematical tests, a spatial test using a buzzer loop (a variant of the classic mirror tracing task) (Feldman, P. J., Cohen, S., Lepore, S. J., Matthews, K. A., Kamarck, T. W., & Marsland, A. L., 1999), and a social test involving role-play. The reason for using a variety of tests was because in initial pilot tests, the conventional Stroop word/colour test (Renaud, P., Blondin, J. P., 1997) was used, but failed to elicit any stress response in a number of subjects who were designers. It was rejected on that basis for future use with those participants. This would seem to suggest that reaction to stress induction is governed by the individual difference model (Dickerson, S. S., Kemeny, M.E., 2004). After the participant had exceeded 10% over the baseline heart-rate for a continuous period of at least one minute, a video piece was actuated via the laptop, i.e. the video piece was actuated in direct response to an extended breach of the

10% HR threshold. The reaction of the user to the video intervention was monitored throughout by continuous HR sensing while viewing the video piece. Not all of the subjects were monitored for the full duration of the video, in part to recurring technical issues with porting data to the laptop.

Data Analysis

In processing the data, where data was missing at random, mean replacement was utilised (Bennett, 2001). Where data was judged to be 'missing not at random', (due in all cases to equipment failure), clinical judgement was applied to exclude anomalous HR data from the averaging process. This occurred typically where the HR signal dropped suddenly to a '0' value, due to loss of transmission. HR was sampled once per second, but in order to render the data meaningful both statistically and clinically, it was then averaged over 30 seconds and plotted graphically. The graphs were then inspected visually, on the basis that the experiment design requires a minimum 15 participants in order to carry out a statistical analysis, and usable data was obtained from 6 participants only during the pilot tests. The time at which HR was observed to return to baseline was established from graphed data.

RESULTS

Participants typically showed an increase in HR after undertaking tasks designed to induce stress, followed by a rapid decrease in HR after the video is activated, when coincides with the point at which the threshold HR has been continuously breached for one minute. The stress-inducing tests were terminated at the same juncture, i.e. when the video was actuated. Five out of 6 participants showed a brief increase in HR immediately after the video was actuated, prior to a decrease. Times, indicated in hours, minutes and seconds on the horizontal axis, are recorded clock time. The time period between Baseline HR marker and Video Actuation is the period in which participants were subjected to stress induction. The baseline HR marker triggers actuation of the video.

Actual clock time

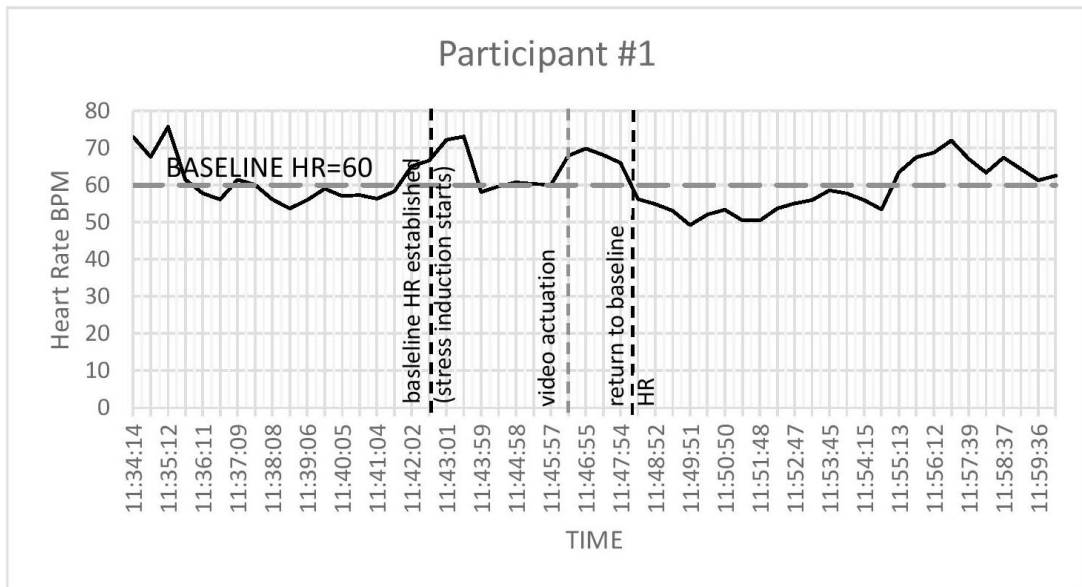
	Start time	Baseline HR	Video Actuation	Return to Baseline HR
#1	11:34:14	11:42:28	11:46:24	11:48:15
#2	14:33:36	14:42:35	14:47:25	14:48:43
#3	10:57:10	11:02:08	11:08:42	11:09:15
#4	15:07:11	15:16:09	15:17:36	15:18:35
#5	15:00:55	15:09:54	15:13:34	15:15:33
#6	15:11:07	15:16:03	15:17:23	15:19:24

Time elapsed in minutes and seconds

	Start time- Baseline HR	Baseline HR- Video Actuation	Video Actuation- Return to Baseline HR
#1	8:14	3:56	1:51
#2	8:59	4:50	1:18
#3	4:58	6:34	0:33
#4	8:58	1:27	0:59
#5	8:59	3:40	1:59
#6	4:56	1:20	2:01

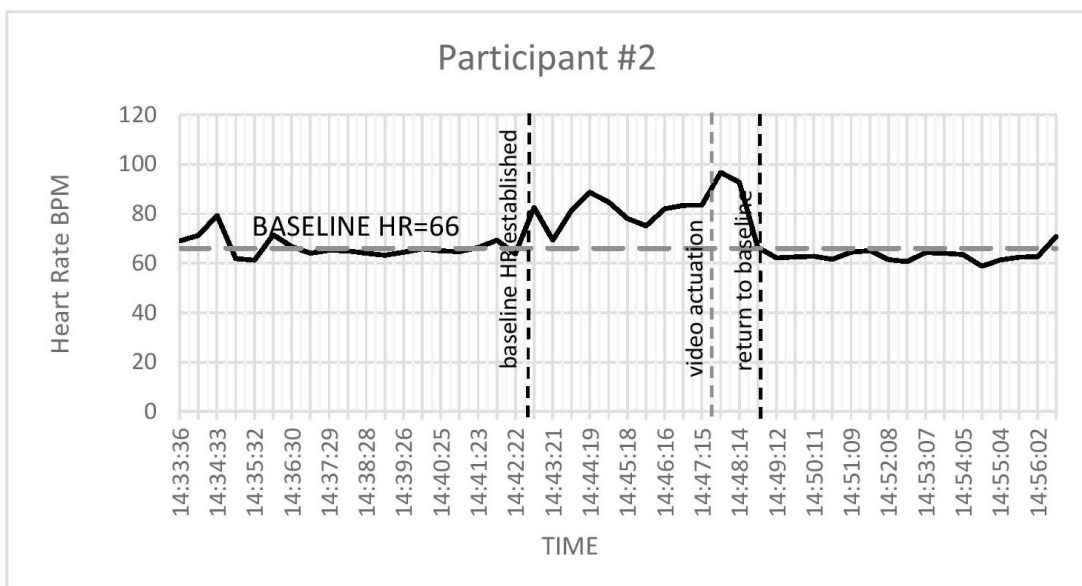
Participant #1

Initial increase in HR after video actuation, followed by rapid decrease below baseline, remaining below baseline for approximately 7 minutes before rising again, then dropping almost to baseline again at the end of the video.



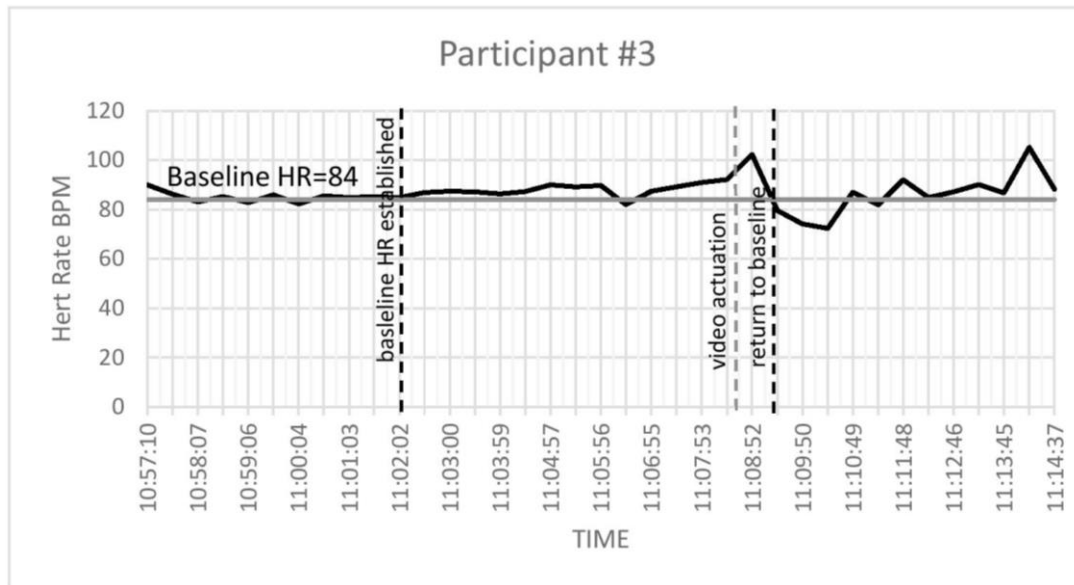
Participant #2

Slight increase, followed by sharp decrease in HR after video actuation, with HR remaining very slightly below baseline for approximately 8 minutes, rising slightly close to the end of the video.



Participant #3

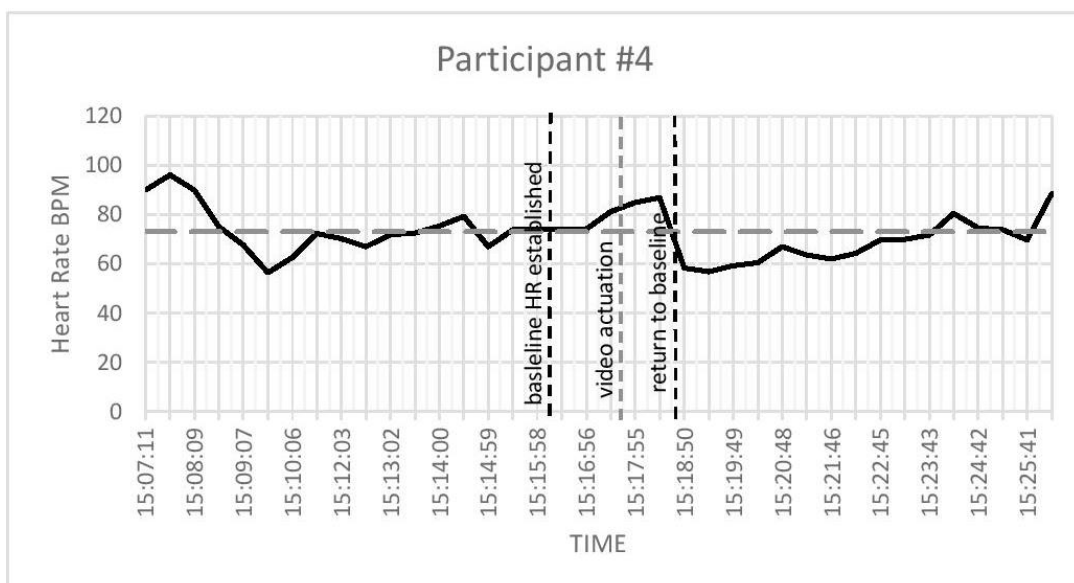
Slight increase, followed by sharp decrease in HR to below baseline after video actuation, in this participant the HR goes above and below threshold between actuation and the end of the video, possibly in response to specific images.



Participant #4

Increase in HR after video actuation, followed by a rapid decrease, remaining below baseline for approximately 6 minutes, and rising towards the end of the video.

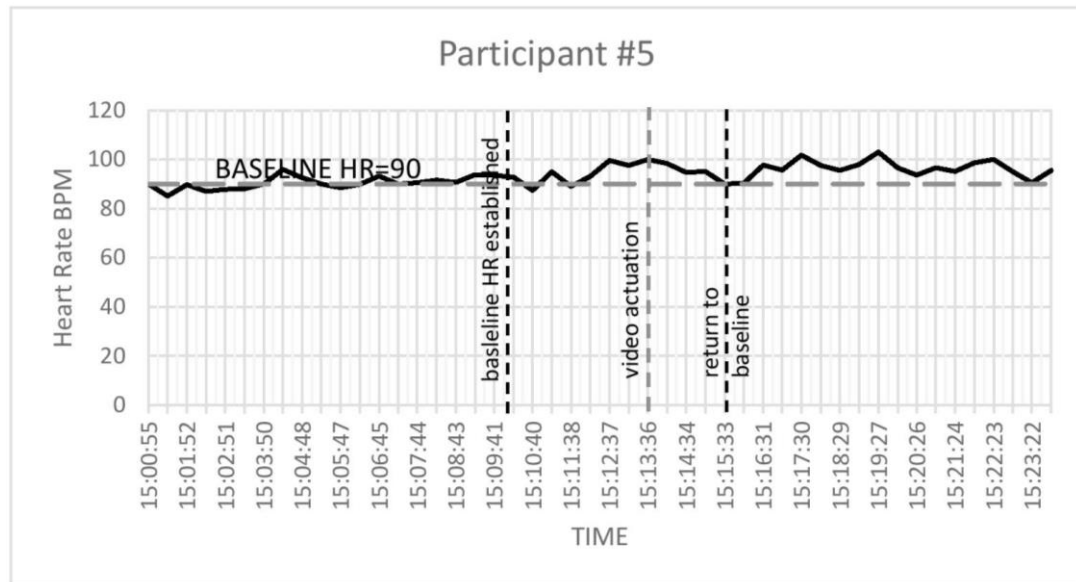
Missing data from 15:18:22 to 15:18:33 implies that actuation was delayed slightly.



Participant #5

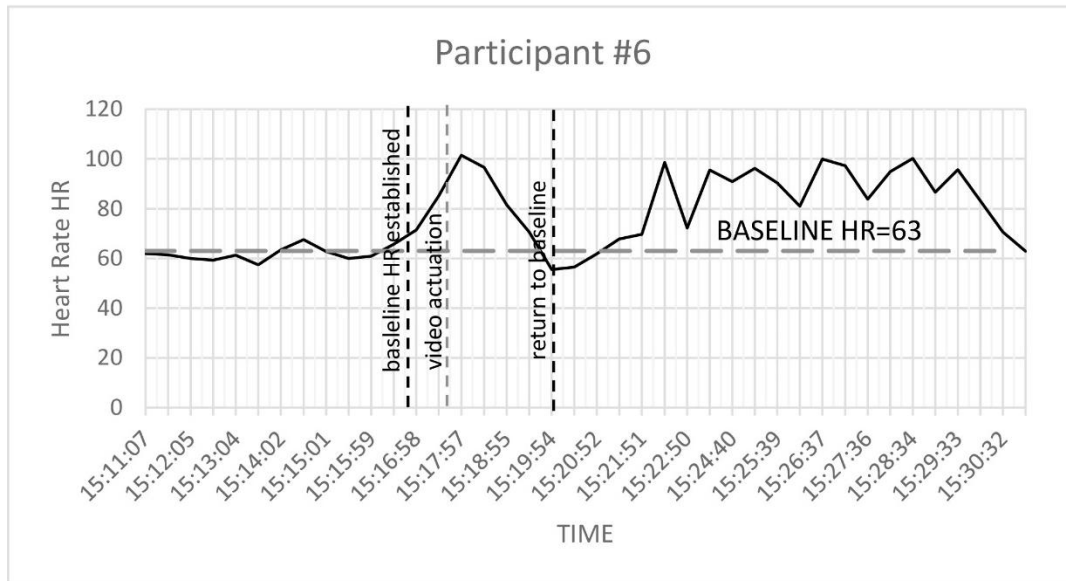
Slow decrease in HR after actuation, with variable HR, above baseline, to end.

Overall, no discernible effect, overall slight increase in HR after video actuation.



Participant #6

Very sharp decrease in HR immediately after video actuation. However, having reached the baseline value, HR increased again remaining variable and well above the 10% threshold value while the participant viewed the video. While not displaying HR values consistent with a de-stressing response, this participant reported that some of the imagery generated feelings of reminiscing. The larger observed variations in HR may relate to the participant being more reactive to stimulus than other participants.



Discussion

The swift decrease in HR after actuation of the video, indicating a decrease in stress, which was observed in 5 out of the 6 participants, cannot be explained by removal of the stressor alone, but can be explained as a response to exposure to natural imagery, as expected. This reinforces the findings of Wyse and Saito. The typical response was a further, and brief increase in HR after video actuation, (possibly due to the continued effect of stress induction), followed by a sharp decrease. In all subjects, HR returned to baseline level, remaining below baseline for a period of 6-8 minutes in three out of six subjects. This indicates a possibility for obtaining an extended response.

Recovery times from induced stress varied slightly from individual to individual, which is explained by the individual difference model, whereby reaction to stress, recovery from stress, and coping skills are regarded as aspects of personality. The limited sample size of six participants and nature of the results were insufficient for statistical analysis. The preliminary results presented suggest that further research would be productive, but also suggest modification of the experiment design and equipment prior to further research being carried out.

Other observations

Equipment

The very high rate of equipment failure interfered with the reliability of the data collected as any interaction from the researcher in remedying lack of transmitted data signals resulted in an increase in participant heart-rate, as a reflection of arousal, though this was remedied as far as practicable in data processing. The lack of usability of the sensor from both a researcher and participant perspective proved a persistent obstacle. Modifications in future research might therefore include replacing the chest-strap with a more ‘user-friendly’ wearable sensor, including the possibility of making a bespoke wearable sensor, or alternatively the use of a non-intrusive sensing method, such as video analysis of facial expression, using Affdex (REF???) or a similar application. The latter would be particularly appropriate for research in a live care setting, and is also arguably a more architectural approach, as no wearable sensors are utilised, and interaction takes place directly between the person and the built environment. Use of bespoke sensor/sensing methods would also remove common issues with licensing and proprietary software.

Since the experiment, the Shimmer device itself has been modified to include an on-sensor on/off button, and a wrist strap to improve wearability. Previously, the device had to be placed in a pocket of the user’s clothing, (if available) or near the user, when the user was static. The previous absence of an on-off button reduced the usability for the researchers, as the sensor had to be placed in the docking port in order to check if it was switched on. Feedback to the manufacturer on these specific issues was provided during the course of the pilot tests.

ShimmerVideo

The event marker for return to threshold HR value should be replaced with marker for return to baseline HR. The possibility of including markers to examine response

to specific images should be examined if the existing video piece continues to be used.

Projector/Canvas Screen

A larger screen/ area of wall surface might be considered, to increase immersivity, as well as the potential inherent in using transmitted light, rather than projected images. Means of light/image transmission include LED textile and large scale glass screens.

MyRoom Video

Further development of video content for future research should explore prolonging the effects of any de-stressing response. Possibilities for more sophisticated and targeted creative input in future research have been discussed in some detail in Chapter 6. The intention is to progress to the use of more sophisticated and curated visual interventions, most probably involving collaboration with an established visual arts practitioner, with the objective of obtaining a more persistent state of relaxation in participants, prior to testing of such a visual intervention in live care settings, on users with cognitive impairment resulting from dementia. Creative input at this stage of the research was limited, as it was considered to introduce a further variable, though almost any decision in this context can be considered a design decision. The very act of framing a shot for a photograph, or the decision to include or exclude specific images, implies an aesthetic judgment. Therefore, though aesthetic input was restrained, insofar as it possible for any designer to do so, inevitable aesthetic choices were made also in the selection of images, and in their sequencing.

Experiment Design

The experiment design was satisfactory, though research in a live environment will require modification, specifically in order to isolate and contextualise and isolate

relevant sensed HR data. An alternative approach is to first establish the efficacy of the video intervention in a laboratory setting, by pursuing the current approach and modifying it iteratively, prior to deployment in a live setting, where observation and qualitative analysis might be used to obtain data, if no suitable sensing method is available.

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APPENDIX II

Ethics in dementia research: obtaining informed consent

There are particular ethical issues which arise in relation to carrying out research on people with dementia, arising from the global cognitive impairment associated with dementia. In particular, loss of short-term memory, coupled with loss of ability to verbalise, creates issues for researchers, in relation to obtaining and maintaining informed consent from the person (Crossan, B., McColgan, G., 1999) (Berghmans, R., Ter Meulen, R., 1995). This, with other factors, also implies that standard research techniques may not always be appropriate. The increased vulnerability of the person to stressors must also be taken into account. At the same time, it is important to remember that a diagnosis of dementia does not automatically imply loss of ability to give informed consent (Marson, D., Schmitt, F., Ingram, K., Harrell, L., 1994), and also that a person who has diagnosis of dementia can contribute valid information to research, and should not be excluded from participation if research is to have meaning, and especially practical application.

The emergence of the person in dementia research is a relatively new phenomenon (Downs, 1997), and has resulted in approaches to research where information/data is sought directly from the person rather than through a third party, such as a carer or relative. The opinion of a carer/relative may provide the information necessary to make a judgement as to whether or not the person is capable of giving informed consent. In the absence of the possibility of informed consent, initial consent may be obtained by proxy from a relative. Problems with short-term memory imply that it is more appropriate with some subjects, including where only proxy consent is obtained, to maintain that consent is still present throughout the research process, during for example, an interview, by means of the researcher constantly checking back to see if she has the person's agreement to continue with the process in hand (Berghmans, R., Ter Meulen, R., 1995). Informal interaction with the researcher can also give the research participant an insight into the research process. There is an increasing consensus that proxy consent alone is insufficient, and that where it is obtained, continuous monitoring of the person, and their reactions, throughout the

research process is still required, so that consent-gathering itself becomes a process, rather than a discrete event. (Crossan, B., McColgan, G., 1999) (Hubbard, G., Downs, M., Tester, S., 2001)

Techniques for acquiring information

For the person with dementia, the ability to communicate verbally, and lucidly, can vary over time, (including over the course of a single day). Taken together with other age- and dementia-related issues such as hearing impairment, a formal interview, of which verbal comprehension and verbalisation form an implicit component, in itself may not be an appropriate technique for obtaining meaningful information from the person. (Hubbard, G., Downs, M.G., Tester, S., 2003). Repeated questioning is likely to become a source of stress for a person who is unable to answer directly. Alternative recognised techniques for obtaining information, include observation (Cottrell, V., Schultz, R., 1993), and informal conversations, during which useful information, for example about the person's opinion on her environment, can be gleaned. These involve the researcher remaining with the person for longer periods of time. It is also important that the researcher be aware of, and sensitive to, the emotional state of the participant, as the experience of dementia is itself a source of many negative emotions such as fear, anxiety, stress, and grief, for the person with dementia (Bender, M., Cheston, R., 1997). Researchers may need to acquire specific skills in order to successfully communicate with research participants with dementia.

Observation of affect by the researcher from facial expression or behaviour is also an accepted research method for eliciting information about the person's satisfaction (or otherwise) with an environment or situation. (Hubbard, G., Cook, A., Tester, S., Downs, M., 2002) , especially in the latter stages of dementia, though the limited range of facial expression in a person with late-stage dementia makes this difficult (Asplund, K., Jansson, L., Norberg, A., 1995). This last again suggests that an embedded system which is capable of inferring affect from acquisition of bio-data

might prove more than useful in future research, as it may be possible to generate a more complete picture of affect, including in the absence of a carer in close proximity to the person.

In all of the approaches cited, the common and critical aspect is user-centredness, which is a theme of the research proposal. The burden of the research on the participant must always be minimised.

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APPENDIX III

Future Research Plan

The MyRoom proposal as a whole is likely to be most efficiently developed and tested as a research and development project in a 'Living Lab', where applications, hardware and interfaces can be tested singly or collectively, and integrated with architectural and product design into a coherent living environment. In effect what is being developed is a Building Management System which takes user activity and affect into account in the management of environmental characteristics and response.

1. Sensing of the person

The single most critical piece of research is in relation to developing a user-appropriate system of sensors and associated software for sensing of the person. This must be designed and developed so as to be minimally intrusive, which permits a number of approaches, with the development of a fully-embedded system seen as preferable order to maximise ease-of-use for the person with dementia in any residential setting. Certain methods of bio-sensing suggest themselves as being multi-functional in terms of acquisition of useful data, notably use of video, which can be analysed and interpreted to provide data on location, movement, activity, and affect. Any such application should first be tested for reliability in a lab prototype on healthy users, and subsequently, on subjects with early stage dementia, with informed consent. Use of video to infer affect specifically from elderly people with dementia will require dedicated research involving collection of bio-data in situ, (i.e. in a residential care context) and comparison against carer evaluation, in order to develop an application capable of accurate inference of affect from facial expression. The accuracy of identification of affect by a system can be compared against accepted scales of measurement, for example the Facial Action Coding System (Ekman, P., Friesen, W., 1978).

2. Contextualisation of sensor data which relates to user

Wireless sensor systems which collect and respond to contextual data for environmental management are already commercially available. Integration of user data into contextual data will require development of specific platforms to allow communication between sensor systems acquiring user data and those acquiring contextual data, in order to facilitate more accurate interpretation of user data.

3. Intelligent system design

The next stage is the development of an intelligent embedded system capable of facilitating communication and co-ordination between multiple sensors, actuators, software programmes, and platforms. The system must be capable of observation, learning and hence, intelligent decision-making. Such a system is also best first tested in a living lab/ working prototype, to examine the viability of interactions between system components and eliminate undesirable unintended system interactions.

4. Testing in situ

When a working prototype which incorporates affective computing has been developed, it can then be tested longitudinally, in situ in a real-life residential setting. This might be achieved by installing the system in a limited number of rooms, and testing it longitudinally, using rooms with a standard specification as a control. The system as a whole should be designed so as to utilise and integrate into existing wireless networks in buildings, where possible. Testing in situ will require a process of obtaining informed consent from users. However, if the system indicates that a user is becoming overly-stressed when using of certain applications or interfaces, the system can also be designed to self-report such usability issues. Data on the efficacy and usability might be obtained in the following ways:

- a. Qualitative assessment involving the end user, i.e. the person with dementia, using established methods, including interview (where appropriate), informal conversation with researchers, and observation by researchers of non-verbal

signals and behaviour. Such assessment should be repeated at intervals over a period of several months in order to gauge how the system affects quality-of-life for the user.

- b. System feedback which correlates changes in affect with specific actions/interactions.
- c. System feedback which records longer-term changes in affective state.
- d. Carer feedback, through interviews at intervals throughout a longitudinal research process.

5. Lighting system/ambient visual content

Lastly, ambient visual content may be developed, independently or in parallel to the above, through further research, or adapted from current commercially-available products, and integrated into the wireless system as a whole for testing. If developed through subsequent research, visual content and any actuation achieved through sensing should be tested first on healthy subjects prior to testing on people with dementia. In a live situation, a visual intervention might first be tested in a shared area, using a combination of research methods as at 4. above. If positive results are achieved, it would then be re-tested in individual user rooms. Pending the development of non-intrusive and user-appropriate means of sensing, qualitative assessment, involving both users and carers, should be used to measure both short-term and long-term effects. Integration of sensing of affect in due course will effectively enable continuous self-testing of the system.

Appendix IV

ETHICS APPROVAL PROPOSAL

As submitted to School of Applied Psychology, UCC

MyRoom Research Proposal

The purpose of the experiment is two-fold:

Firstly, it represents a very simplified part-prototype of a responsive environment enabled by wireless technologies, where responsivity is enabled in reaction to psychological affect (rather than ambient environmental conditions). It demonstrates that realtime environmental change can be elicited in response to bio-sensing, serving as a proxy of psychological arousal. That is, the response is personalised by actuation once a specified personal stress threshold is surpassed. The remainder of the PhD thesis comprises a more comprehensive design and technical description of a patient care room, which is responsive to both functional and psychosocial needs. The notion of affective responsivity in the built environment is novel.

Secondly, it aims to reinforce existing but preliminary research by Wyse and others, which demonstrates the efficacy of natural and fractal images in stress relief. As the responses observed in previous experiments (recovery from laboratory stress challenges) were achieved rapidly, this experiment will examine these responses over a longer period of time, and examine change effect over time. The research questions arising from this are: Does the de-stressing response maintain potency? Is there any additional reduction in stress or other effect obtained from being exposed to a video piece with definite creative input?

Bio-signals used as indicators of stressed states (heart rate and galvanic skin response (HR and GSR respectively) will be continuously monitored, and real-time changes indicating stress response will be used to actuate a stress-relieving video installation in direct response to the sensed data. The reaction of the user to the installation will be monitored throughout by continuous bio-sensing.

The video piece proposed for the experiment consists of a series of unedited images of natural scenes and objects, presented as an extended slideshow of 10-15 minutes' duration. None of the scenes or objects are expected to cause distress.

Natural imagery is known to have a stress reducing effect on observers; however, research to date is preliminary and has only involved a limited number of static images. It is expected that continued exposure over a period of 10-15 minutes will result in the observation of bio-signals which are characteristic of the relaxation response. In this case, HR and GSR are being monitored as they are standard and accepted indicators of stress arousal. This research might thus be regarded as a preliminary exploration of the effects on stressed states of more extended exposure to visual stimulus based on natural images, in an architectural context.

If initial results are suggestive of a stress-reducing effect of imagery, a second video installation may be tested. This will consist of an "art piece", where images of natural objects and scenes are digitally manipulated and animated, with creative intervention. The experiment will guide further research into inducing a more persistent relaxed state in a passive observer, starting with testing of second and further video interventions, into an exploration of repeated exposure over time carried out through longitudinal research, on specific populations, including subjects in care settings.

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UCC/CIT, 9/10, Copley Street, Cork.

cathydalton2306@gmail.com

The research is being carried out in collaboration with Dr. Samantha Dockray, School of Applied Psychology, UCC.

Information Sheet for Participants

Purpose of the Study. As part of the requirements for a PhD in Architecture at Cork Centre for Architectural Education (UCC/CIT), I am carrying out a research study, which is concerned with the effects of environmental changes on wellbeing.

What will the study involve? You will be asked to fill out a brief questionnaire on personal wellbeing, and then to carry out a visual test of reaction times on a laptop/pc, while your heart-rate (HR) and skin-conductance (GSR) are continuously monitored. After a short period, your sensed signals will activate a video piece composed of natural images, which you will view for approximately 15 minutes. While viewing the video, your HR and GSR will continue to be monitored. The study will involve just less than one hour, on a once-off basis.

Why have you been asked to take part? You have been asked because you are generally suitable to provide data for your study.

Do you have to take part? Participation is voluntary. If you agree to participate you'll sign a consent form, and will be given copy of this information sheet and the consent form. You can withdraw at any time even if you have agreed at first to participate. You can withdraw your permission to use your data within two weeks; if you withdraw permission, then the data will be permanently deleted.

Will your participation in the study be kept confidential? Yes. No clues to your identity appear in the thesis. Information and results will be kept entirely anonymous.

What will happen to the information which you give? The data will be kept confidential for the duration of the study. On completion of the thesis, the data will be retained for a further six months and then destroyed.

What will happen to the results? The results will be presented in my thesis. They will be seen by my supervisor, a second marker and the external examiner. The thesis may be read by future students on the course. The study may be published in an academic journal.

What are the possible disadvantages of taking part? I don't envisage any negative consequences for you in taking part.

What if there is a problem? At the end of the procedure I will discuss with you how you found the experience and how you are feeling.

Who has reviewed this study? Approval must be given by the UCC Department of Applied Psychology Ethics Committee, and this approval has been granted to this study.

Any further queries? If you need any further information, you can contact me: Cathy Dalton (086) 8220335 cathydalton2306@gmail.com

Cathy Dalton, PhD Candidate,
Cork Centre for Architectural Education,
UCC/CIT, 9/10, Copley Street, Cork.

cathydalton2306@gmail.com

If you agree to take part in the study, please sign the consent form overleaf.

Consent Form

I _____ agree to participate in Cathy Dalton's research study.

The purpose of the study has been explained to me and I understand it.

I am participating voluntarily.

I agree that no payment will be made to for participation.

I give permission for such personal details as I have provided to be kept on record.

I understand that I can withdraw from the study, without repercussions, at any time whether before it starts or while I am participating.

I understand I can withdraw my permission to use the data within 2weeks of the study, in which case the material I have provided will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

Signed _____ Date: _____

**Department of Applied Psychology, University College Cork
Ethics Approval Form (M Phil, PhD)**

Name of researcher: Cathy Dalton, Dr. Samantha Dockray
Name of supervisor: Prof. Kevin McCartney, Dr. James Harrison
Degree registered for: PhD in Architecture
Date of this document: 22 June 2012
Is this document a clarification? No
Date of previous version: n/a
Sections modified: n/a

> 1. Aims of the project

The proposal represents preliminary research into the effects of designed intervention in the built environment on users, in relation to psychosocial function and congruence, and specifically in relation to the capacity of the built environment to affect perceived stress in users.

> 2.1 Estimated start date: July 2012

> 2.2 Estimated end date: July 2013

> 3. List of methods and measures to be used in the project:

> 4. Do any methods or measures raise the risk of participants experiencing either physical or psychological distress? If any do, outline how the distress will be managed or alleviated:
No, none anticipated. The Stroop test does not result in long-term stress or change in emotional aspect.

> 5.1 Description of participant sample(s) - who is the focus of this research and why:
Convenience sample of healthy adults aged 18-45.

> 5.2 Method of sampling participants, approximate number of participants expected:
Snowball recruitment:
UCC email plus notices on campus at Cork centre for Architectural Education.
Total required number of participants = approximately 15-20

I have consulted the PSI Code of Ethics and present the following analysis as evidence of having satisfied the requirement of considering how to proceed ethically with my research.

 (signature of researcher)

(signature of researcher)

I have consulted with the researcher and consider the account given in this document to be a true description of the ethical implications of the work proposed for my supervision.

 (signature of supervisor)

(signature of supervisor)

Participants

Check whether any of the following descriptors apply regarding the participants. If any do apply, then indicate in the space below how ethical issues with regard to participation will be handled. If any issues require clarification, please indicate on this form and attach a supplementary statement.

Participants include:

- > 6. Children under the age of 18 years No
- > 7. People with cognitive or communication difficulties No
- > 8. People with emotional difficulties No
- > 9. People or patients in institutions No
- > 10. People in custody No
- > 11. People engaged in illegal activities No
- > 12. Any other people who may be particularly at risk No
- > 13. Any other people who cannot give explicit informed consent No
- > 14. Animals No

Ethical Issues

Consider the following ethical issues regarding research with people and indicate whether your research raises a problem under the issue. If it does, then summarise how your research will deal with the problem. If any issues require clarification, please indicate on this form and attach a supplementary statement.

- > 15. The research avoids misleading the participants in any way Yes
- > 16. The main research procedures will be described to the participants in advance so that they will be informed of what to expect Yes
- > 17. Participation will be voluntary Yes
- > 18. Participants will give explicit informed consent Yes

- > 19. Participants will be told they may withdraw from the research at any time for for any reasons and (where relevant) may omit answering questions to which they do not wish to respond Yes
- > 20. Participants will be de-briefed at the end of their participation No,not necessary
- > 21. Data will be treated with appropriate confidentiality and anonymity Yes
- > 22. Data will be treated in conformity with the Data Protection Act (2002) Yes

Authorisation

Date when this research was considered by the Postgraduate Research Committee of the Applied Psychology Department:

Result (please check one):

- ☐ Approved
- ☐ Approved with minor comments (resubmission is not required)
- ☐ Approved pending clarification (a list of sections and required clarifications must be made below or appended)
- ☐ Approved pending approval from external body (the body or bodies from which approval is pending must be specified)
- ☐ Not approved

This result reflects the decision of the Postgraduate Research Committee made on the above date

_____ (name of chairperson)

_____ (signature of chairperson)

References

- . PSI Code of Ethics
- . BPS Code of Ethics
- . Data Protection Act