

Senses, Brain and Spaces Workshop

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Peter Barrett
Lucinda Barrett



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Executive Summary

This workshop, held on 8 and 9 March 2007 in the dynamic environment of the Think Lab at Salford University, brought together people at the forefront of neuroscience and sensory perception research, as well as artists and designers making an original contribution to the way we view our environment. Twenty-seven invited international experts attended from Canada, Denmark, Holland, Italy, Portugal, UK and the USA. The companies represented included Sainsburys, Manchester City Council, Barclays, the BBC and Philips Lighting. The aim was to engage in a discourse on the multiple factors involved in the holistic sensation of spaces by individuals.

Brief individual presentations to instigate discussion were combined with group interaction and moderated plenary debates. Four group sessions were held within the workshop and in each session the groups were divided up into the various use specialties, namely: schools, housing, retail and offices. A virtual model of a school had been developed and this was used at one point to help shift the groups' thinking to a design mode.

Analysis of the early memories, provided by participants in advance of the workshop, revealed a very complex set of perspectives. Aspects, such as cramped space, that might be expected to have negative connotations were quite often positive. Social context was important and linked to the need for personalisation of spaces. People seemed to calibrate spaces through comparison to other more positive memories of space and individuals could inhabit spaces physically, or imaginatively transcend them. The various memories have been grouped under five main sections: those dealing with large spaces, cramped spaces, sense factors, individualisation, way-finding and a decay/destruction/décor category.

Various presentations were made on discrete sense dimensions, namely: acoustics, colour, air quality / smell, natural and artificial light and planting. These highlighted a recurrent theme around the dynamics of the experiences involved. This was in two ways: the changing nature of human needs over time (whether within a day or over years); and the complex interactive effects between the various sense experiences, both physiologically and socially driven. Another recurrent theme was that of "naturalness".

It would seem that humans do have characteristics derived from our evolutionary roots and these are likely to underlie the recurrent impact of dimensions of nature. The complexity is rooted in the fact that spaces are, in practice experienced by individuals holistically and interactively. At a base level this is confounded by the cognitive limits of humans, so that perception becomes an "ill-posed question", in which the brain endeavours to represent reality probabilistically, as best it can. This capacity varies over a life time, generating different needs at different times. This practical complexity is compounded by the psychological and sociological layers of issues associated with spaces, such as status, control and social belonging. Alongside all of this is the dynamic human "design" tendency to imagine, experience and reflect on spaces, so progressively seeking better solutions. Thus, finding optimal solutions is not a simple search for *the* answer. It is, rather, a subtle process of addressing multiple aspects and moving towards a better understanding of the questions we need to address. Elegant solutions can then more confidently be derived at the dynamic interface of spaces and individuals over time.

The group work and subsequent discussions identified the broadly elements of an agenda for action. This has three components: first, responding to user needs, second, the knowledge base regarding impacts of spaces on behaviour, and third, process issues concerning the co-production of design. In a bit more detail:

First, the particular aspects of *“responding to user needs”* highlighted by the workshop were:

- Age dependency issues
- Identity and personalisation aspects
- Wellbeing-health
- Ownership
- Navigation
- Learning
- Belonging and community

Second, the particular aspects of the *“knowledge base regarding impacts of spaces on behaviour”* highlighted by the workshop were:

- The need for a better definition of the knowledge base to help improve design drawing from neuroscience, psychology, sociology and physiology.
- The need for greater understanding of the relationship between design choices and behaviour.
- The ethical aspects of how this knowledge might be used to manipulate people.

Third, the particular aspects of *“process issues concerning the co-production of design”* highlighted by the workshop were:

- The involvement of users in the design as an iterative process, moving from the ‘inside’ responding to needs through mechanisms such as briefing /consultation and to the ‘outside’ where the building is seen as an entity. Further to discover from users whether their needs have been met. It as felt that these processes should have an element of serendipity, so that the place of chance is acknowledged within the design process.
- The evidence base should lead to informing design policy and strategy for example in terms guidelines and norms.

These three generic areas are highly interdependent. How they can inform actions in each of the use areas, with different stakeholders and operating in a variety of markets, needs careful study.

Of course a report cannot hope to capture the depth of the expertise present in the participants or the richness of the discussions that took place. So, further collaboration is key to making real progress. There was a strong consensus that the momentum created by the workshop should be built upon.

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1 Introduction

This workshop, held on 8 and 9 March 2007, brought together people at the forefront of neuroscience and sensory perception research, as well as artists and designers making an original contribution to the way we view our environment, to engage in a discourse on the multiple factors involved in the holistic sensation of spaces by individuals. The purpose of the workshop was to start the process of developing models that can improve the theory and practice of optimising built spaces to improve well-being and the achievement of full human potential drawing from these different expert perspectives.

Twenty-seven invited international experts attended from Canada, Denmark, Holland, Italy, Portugal, UK and the USA. The companies represented included Sainsburys, Manchester City Council, Barclays, the BBC and Philips Lighting. Professor Peter Barrett hosted the event in collaboration with Dr John Zeisel and Professor Jacqueline Vischer. This innovative meeting linked a wide variety of expertise using the dynamic environment of the Think Lab at Salford University. For further details of the SBS workshop and the Think Lab see www.rgc.salford.ac.uk/peterbarrett .

2 Programme Design

2.1 Participants

In order to capture wide expertise and experience a framework was created with five major dimensions: user groups, sensory dimensions, design, neuroscience expertise and the last group that encompassed psychologists and sociologists and creators focusing on individual responses. The organisers then selected and invited people to provide short presentations on the chosen fields.

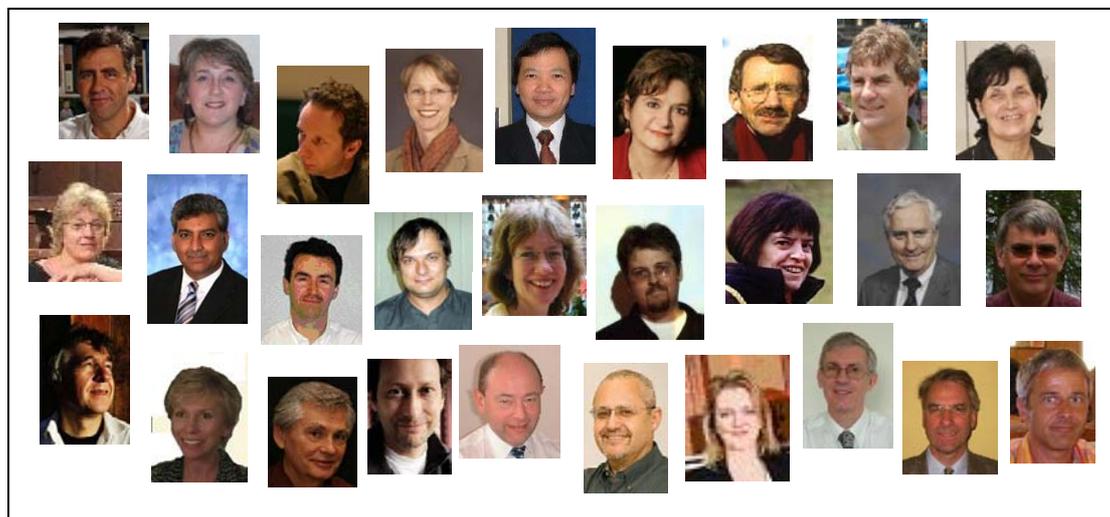


Figure 1: The Participants

Taking the senses group, this spanned across the different senses that are pivotal in perceptions about our environment: sound, smell, sight, including colour and light, artificial and natural, and natural planting. The dimension of taste was omitted. Alongside these, participants were identified with expertise about different use groups: offices, schools, retail, and housing, with this last focusing especially on the specific needs of the elderly. Designers were selected often having a focus within a

specific use area. The neuroscientists were chosen because their work demonstrably related their specific expertise to the area of design and environment. The last group had expertise in the area of individual responses to space issues and also the social processes involved in different environments and contexts. Table 1 summarises the participants and their interests.

Table 1: Participants' Affiliation and Interests

Name	Affiliation	Interests
Tom Albright	Salk Institute, USA	Neuroscience of colour
Lucinda Barrett	University of Salford, UK	Literary theory
Peter Barrett	University of Salford, UK	Facilities management/briefing
Rita Carter	Author, UK	Neuropsychology / brain function
Helen Dodd	Barclays Bank, UK	Network Development
Ian Drumm	University of Salford, UK	Acoustics – enclosed spaces
Maria Joao Durao	Lisbon Technical University, Portugal	Colour and light in Architecture and Design
John Eberhard	ANFA, USA	Human response to built environment
Johnny Grey	Johnny Grey Design, UK	Kitchen design
Lars Gunnarsen	SBi, Denmark	Air quality indoor
Tom Hartley	University of York, UK	Psychology – spatial memory
Philip James	University of Salford, UK	People and environments
Alan Johnson	Hunter Partners, UK	User awareness and social environments
Kjeld Johnsen	SBi, Denmark	Users' perceptions of natural light
Larry Kirkegaard	Kirkegaard Associates, USA	Acoustics/theatres/performance venues
Martine Knoop	Philips Lighting, The NL	Human lighting requirements
Yiu Lam	University of Salford, UK	Building and environmental acoustics
Adrian Leaman	Useable Buildings, UK	Users' needs for buildings
John Lorimer	Manchester City Council, UK	Future school buildings
Rita Newton	University of Salford, UK	Interaction with environments
Simons Parsons	Children's BBC, Scotland	Communicating / entertainment
Evelyn Pellow	Enabling Concepts, UK	User involvement in design/applications
Neil Sachdev	Sainsbury's, UK	Optimising retail environments
Paul Sermon	University of Salford, UK	Creative virtual spaces
Jacqueline Vischer	University of Montreal, Canada	Environmental psychology/work environments
Ashley Weinberg	University of Salford, UK	Occupational psychology
John Zeisel	Hearthstone Alzheimer, USA	Environments for memory and learning

2.2 Pre-workshop work

Prior to the workshop participants were invited to send material to the event (SBS) website. This included a short biography, recommended reading for the workshop bibliography and a short memory from their childhood focusing on a poor space. The brief on this was left quite open in order not to limit the responses. This was by its very nature a small sample, but these password protected memories did provide an unusually intimate view of childhood responses to built environments, that often included information about how that the experience had gone on to affect the adult. These memories were then analysed textually, and using NVivo software, so that for example the frequency of a given word could be charted. The results of the analyses of these memories are summarised in Section 3 below.

2.3 Workshop Programme

Brief individual presentations to instigate discussion were combined with group interaction and moderated plenary debates. Four group sessions were held within the workshop and in each session the groups were divided up into the various use specialties, namely: schools, housing, retail and offices. Membership of the groups varied between the sessions in order to maximise creative inputs and expertise to the process, with only the 'use' expertise staying as a constant. Despite these changes in the groups the core specialties were always represented, so that a designer, a

neuroscientist, sense specialists, and use representative(s) were present. A summariser was identified in each group to record the main outputs.

Each of the four group sessions was guided by a particular expert. The first session was 'use' led and focused on identifying five major problematic issues. The second and third were led by neuroscientists and looked at these problems to develop a range of actionable solutions. Within each of these two sessions the group focused around a pair of allocated neuroscience paradigms, such as memory / learning and sensory perception. After these sessions plenary group work was used to summarise, feedback and discuss the ideas generated. A virtual model of a school had been developed and this was used to help shift the groups' thinking to a design mode through modelling the interactive effects of various ideas. A second model was also shown illustrating how a design consultation process had been used by Enabling Concepts for housing schemes for elderly residents. The final group session was guided by the designers, working on linking the problematic issues with the emergent range of actionable solutions by identifying high leverage actions and longer term research themes.

Following on from this were plenary sessions to debate the emerging themes and start to identify future activities to take them forward.

Table 2 gives the programme in detail. Table 3 shows how the mix of participants was established and progressively re-formed to provide a balance between stimulating new combinations with underlying continuity.

The following sections provide summaries of the presentations and the outputs of the group work and plenary discussions.

Table 2: Senses Brain and Spaces Programme

Senses, Brain and Spaces Workshop - 8/9 March 2007

DAY 1		
Introduction	1.30	Session 1 - Welcome PB/LB <i>Welcome all, feedback the "early memories" synthesis and introduce the intent and structure of the workshop.</i>
	1.50	Session 2 - Ice-breaker LC/PB <i>People to creatively make several bi-lateral introductions</i>
Stimuli	2.00	Session 3 - Framing the issues JZ/JV/TA <i>Short conceptual presentations from a designer, psychologist and neuro-scientist. Some time for discussion about each.</i>
	2.50	Session 4 - Virtual space PS <i>Experimental demonstration of experiencing virtual space.</i>
	3.05	<i>Brief tea break!</i>
	3.20	Session 5 - Sensory perspectives LK/MD/LG/KJ/MK/PJ <i>Six brief presentations plus discussion on specific sensory dimensions, eg colour / light, smell, acoustics, etc</i>
User challenges	4.45	Session 6 - Use orientated group work - problematic issues <i>Form groups around schools, housing for the elderly, offices and retail, <u>led by "use" experts</u>, briefing group members at start. Brainstorm key "problematic issues" related to a SBS approach.</i>
	5.45	Transfer to The Lowry for dinner
DAY 2		
8.30 for ...		
Neuro-science solutions	8.45	Session 7 - Neuro-science paradigm group work 1 <i>Same four use orientated groups reconvene now <u>led by neuroscience experts</u>. Focus on actionable solutions to the problematic issues from Session 6 around two of the following: memory / learning, cognitive mapping / way-finding, physiological / physical ability and sensory perception.</i>
	10.00	Session 8 - Neuro-science paradigm group work 2 <i>Four new use orientated groups <u>led by different neuroscience experts</u>. Focus on actionable solutions to issues around remaining two areas.</i>
	11.00	<i>Brief tea break!</i>
	11.15	Session 9 - Plenary feedback / discussion <i>Summaries of group work presented and discussed in plenary session.</i>
Environmental press solutions	12.15	Session 10 - Plenary debate around virtual model <i>All apply their emerging ideas to a virtual school in order to highlight complex interactive effects</i>
	1.00	Lunch
	1.45	Session 11 - Environmental press / comfort paradigm group work <i>Four new use orientated groups <u>led by designers</u>. Focusing on linking problematic issues with a range of actionable solutions. Resulting in the identification of high leverage actions and from these proposals for two research themes that would improve understanding / performance in the design / planning of those settings</i>
	3.00	<i>Brief tea break!</i>
Synthesis / way forward	3.15	Session 12 - Plenary presentations / discussion <i>Summaries of group work presented and strong emergent common research themes identified.</i>
	4.00	Session 13 - Final summary / discussion / next steps PB/JV/JZ <i>Summary of the outputs of the workshop in terms of problematic user issues, solution areas, useful paradigms (meta-views) and high leverage points leading to emergent research themes. Plenary discussion of the priority areas for development.</i>
	5.00	Session 14 - Thanks and closing / wine + cheese <i>Informal finish allowing time for relaxing and ensuring connections in place for future activities.</i>
5.30		

Table 3: Group Membership

SBS group membership

Disc	Name	Session 6 - User led				Session 7 - Neuro led 1				Session 8 - Neuro led 2				Session 11 - Designer led			
		Retail	Offices	Schools	Housing	Retail	Offices	Schools	Housing	Retail	Offices	Schools	Housing	Retail	Offices	Schools	Housing
U	Neil Sachdev																
S	Martine Knoop																
N	Rita Carter (Topics A / B)																
D/P	Paul Sermon	*								*							*
U	Adrian Leaman																
S	Yui Lam					*				*				*			
U/P	Jacqueline Vischer																
S	Maria Joao Durao																
U	Helen Dodd																
N	Tom Hartley (Topics C / D)																
S	Ian Drumm															*	
P	Ashley Weinberg						*				*			*			
S	Philip James		*														
U	John Lorimer																
D	Alan Johnson																
S	Larry Kirkegaard																
P	Simon Parsons																
N	Tom Albright (Topics A / D)																
S	Kjeld Johnsen																
P	Peter Barrett			*													
U	Evelyn Pellow																
D/P	John Zeisel							*									
S	L Gunnarsen																
D/N	John Eberhard																
N	David Melcher (Topics B / C)																
D	Johnny Grey																
U	Rita Newton				*				*			*					

Disciplines

- U = User
- S = Sensory
- D = Designer
- N = Neuroscience
- P = People Perspective

Special roles

- = group "guide"
- * = summariser

Neuroscience paradigm-led topics for Sessions 7 and 8

- Topic A = Sensory Perception
- Topic B = Cognitive Mapping and Wayfinding
- Topic C = Physiological and Physical
- Topic D = Memory and Learning

3 Summary of Introduction (Sessions 1 and 2)

All the PowerPoint presentations from the workshop can be found on the Senses, Brain and Spaces website at: www.rgc.salford.ac.uk/peterbarrett.

Peter Barrett, Pro Vice Chancellor for research at the University of Salford, opened the workshop with a presentation that set out the intent and structure of the workshop. This included his vision for it within the research area of Revaluing Construction that brings a sharper focus on the systemic contribution of the built environment. In this context the impacts of spaces on the health, well-being and behaviour of individuals is a, if not the, fundamental building block to understanding the role of the built environment in society.

Following on from this Lucinda Barrett provided an analysis of the early memories provided by participants in advance of the workshop. A simple count of their incidence gave some measure of the importance of various aspects in these memories, such as darkness and cramped conditions, which were frequently discussed. However, this did not provide a full picture of a very complex set of perspectives.

Beyond sheer incidence, the strength of the responses varied noticeably, so that for example smells were not only frequently discussed, but were also very strongly affecting memories. Another complicating factor was that aspects such as cramped space that might be expected to have negative connotations were quite often positive, and associated with excitement. Also the social context of the space was central. Other people could make these spaces comforting or more disturbing depending on the context. For example, lots of other children in a playground, zoo or school dining room did, for some, increase the feeling of alienation. The need for personalisation of spaces was also noted frequently, and the role of size and scale were also mentioned in situations where the individual felt lost in their space.

Another recurrent feature of the memories seemed to be the need to calibrate them through comparison to other more positive memories of space. So for example participants contrasted: domestic dining with school canteens; a sterile hospital with the colourful African landscape outside of it; private and public hospital rooms; the urban and rural environments; and schools that contained both grand architecture and poorly designed extensions. Further, acceptance of poor spaces seemed to be closely related to how long they had to be endured. Thus, perceptions of the spaces seemed to be a result of some dynamic between physical features, other people and the individual themselves. For example, individuals could inhabit spaces physically, or imaginatively transcend them by remembering nicer environments or finding a hopeful view.

The various memories have been grouped into a framework under five main sections: those dealing with large spaces, cramped spaces, sense factors, individualisation, way-finding and a decay/destruction/décor category. Many of the reactions could have been listed under several headings, but a choice was made gauged on the strength of reaction. As the table below shows these spaces all had specific reactions. An abiding impression is the force of the memories even many years later, and the lasting impact on behaviour or preferences.

Table 4: Categories from Early Memories

Category	Space	Reaction	Notes
<i>Large spaces / Scale</i>	Factory	Monotony	View of clock
	Playground	Shyness	
	Railway	Frustration	
	School dining room	Alienation, revulsion	Compared to domestic setting
	Zoo bars	Isolation, lost	
	Playground walls	Isolation, lost	
<i>Cramped spaces</i>	Child's den	Excitement, control	Excitement overcomes poor physical - cold, damp, dark
	Car	Danger	
	Attic	Excitement	Family treasure overcomes poor space - dark, stuffy, cramped
	Basement rooms	Social and comfort	Social aspects overcome poor physical - cramped, little daylight.
<i>Sensory Factors</i>	Lorry smell	Contamination	Lasting sense
	Railway station noise	Frustration, confusion	
	House gloom	Oppression	View to plants improves it
	School food smell	Revulsion	
	Hospital ward smell, noise	Depression	Moving from private to public wards
	School dining room - food and smell	Sense of being controlled	
	School rooms - visual, heat, light	Depressing, poor learning	Strong contrast between two areas of school
	Civic building- sound	Transformation from circus to symphony concert space. Mystery and wonder.	Different sensual experience in same space.
	Hospital monochrome	Resentment	Comparison to African landscape
<i>Individualisation factors</i>	Bedroom	Invasion of privacy	
	House uniformity	Monotony disturbing.	
	Boot Camp	Alienation	
<i>Way finding</i>	Zoo	Isolation	
	School	Confusion	
<i>Decay/Destruction/ Decor</i>	Decay in house	Threatened	
	Vet's rooms - decor	Sorrow	
	School chair - spoiled	Regret	
	Doctor's waiting room- decor	Particularity of décor associations	

4 Summary of Framing Perspectives (Sessions 3 and 4)

4.1 Design

Dr John Zeisel, visiting professor at the University of Salford and founder of Hearthstone Alzheimer Care, gave a presentation describing the three aspects of the design process each of which occurs in particular locations within the brain. These are imaging (the envisioning aspect), presenting (the communicating these ideas and plans) and, lastly, the testing phase (comparing images against knowledge). Within each of these stages a conceptual shift occurs that brings one closer to an acceptable decision. So the different types of creativity involved run from the imaginative conception, to the actions (sensory or motor) involved in fulfilling them, through to the reflective part of creativity that improves or edits an output. The process is cyclical and cumulative, feeding back into knowledge bases, allowing for re-conceptualising along new lines of enquiry.

4.2 Psychology

Professor Jacqueline Vischer, from the University of Montreal, and Visiting Professor at the University of Salford, went on to look at different ideas about our understanding of human behaviour in relation to the physical environment. She described a range of environmental scales at which human behaviour is affected. Various forms of behaviour related to space include those that regulate interpersonal relations, (such as territoriality and privacy) as well as intrapersonal behaviours such as mood, attention and attitude. The complexity of the space-behaviour relationship lies in the mutually interactive effects between the environment and our behavioural responses to it. Looked at in terms of how office building users seek to meet comfort needs at different levels, an effective work environment satisfies our basic physical needs levels, such as safety and security, which forms a basis to meet functional needs that is, support for activities and tasks. Finally, users experience psychological comfort as a result of satisfaction and meeting personal preferences, as well as needs for status and control.

4.3 Neuroscience

Dr Tom Albright, from the Salk Institute and the University of California San Diego, gave the last framing session describing brain structure, the means of connecting between brain areas and giving some sense of how the brain contains the essence of the whole person, going beyond immediate sensory experience to all subjective experience such as memories and ambitions. He went on from this to describe in detail the functioning within the visual system and the brain's part in reconstructing the ambiguous messages that fall onto the retina into a coherent picture. These form an 'ill posed question' so that the brain uses probabilistic rules to create a sense of what one thinks is there. This makes the idea of sight as the arbiter of truth – "I saw it with my own eyes" – rather less compelling! In analysing these activities fMRI (functional magnetic resonance imaging) is used to detect oxygen take-up within different regions of the brain, thus helping to locate different brain functions when used along side behavioural observations.

4.4 Virtual Spaces

Professor Paul Sermon of Salford University talked through video examples of the use of interactive virtual spaces that challenge notions of space as a tangible, temporal, physical commodity. Within this the possibilities of advanced technologies were raised, together with questions about the nature of our senses where sight and touch become, to a degree, interchangeable.

5 Summary of Sensory Perspectives (Session 5)

5.1 Acoustics

Larry Kirkegaard, from Kirkegaard Associates, Chicago talked about acoustics and used his work on the acoustic problems within the Royal Festival Hall to illustrate the issues. The hall had required adaptations to overcome problems for musicians in getting a sense of their own sound. Various physical features had contributed to the problem, the width of the room and the density of the panelling structures and the projective structures that pushed sound out to the audience. This was compared with an older building, the Vienna Musikvereinsaal, a much smaller narrower building with thick masonry walls. Questionnaires that asked musicians about their ease of ensemble, how easy it was for them to play, had shown the superiority of the acoustics in the Viennese hall. Examples were given of the cumulative effect on reverberation time of the different materials and structures, such as carpets, panels, and boxes, at different frequencies.

5.2 Colour

Professor Maria Joao Durao, from Lisbon Technical University, gave the next presentation on colour describing its intersection with psychology and architecture, and its importance in areas such as orientation, differentiating spaces, creating a sense of size, affecting mood and reducing monotony. She described her research on the effects of colour in space modules for the working group of the American Institute of Aeronautics, showing the different attributes of the different schemes. Part of the problems faced by these spaces is the need to differentiate work areas and activities, another is the problem of alignment and maintaining a vertical position in zero gravity, without which balance is disturbed and nausea experienced. Colour is used then to define and separate areas and to give a vertical sense that simulates our experience on earth by placing dark colours lower and the lighter colours higher. Another aspect the research looked at was the functional needs in performance and the different responses to them. For example dark blue/grey colours can under-stimulate, which psychologists' tests have shown leads to restlessness. However a complicating feature is that colour perception is relative, they work in opposition to each other, and so for example a red that has more blue in it can be perceived as cooler than a violet colour, with the dominating colour determining the overall character.

Other aspects that affect perceptions are the expanse of colour and the distance it is experienced from, light is also a major factor in our perceptions of colour. Texture has also been shown to have an impact, providing increased satisfaction when linked to natural elements such as wood. Overall importance was placed on the need for all the elements to be interrelated.

5.3 Air quality and Smell

Dr Lars Gunnarsen, from the Danish Building Research Institute, described our sensory adaptations to indoor air quality. He described the laboratory techniques for investigating our responses to smells using indoor air quality chambers called Climpaqs, a cone shaped article used to deliver particular smells within very clean laboratories. Scaled questions are then posed to gauge the level of dissatisfaction human subjects would feel about the smell for an assumed space, such as an office, at a variety of ventilation rates. Understandably the dissatisfaction falls away as ventilation increases. Further measures are taken to determine how quickly adaptation occurs, that is the process by which we stop consciously perceiving the

smell. Experiments showed that for natural human body smells this happened quite quickly whereas for tobacco and building material smells this took a lot longer. Other work had been done to determine the interactive effects of various dimensions, for example the relative importance of excessive temperature compared to excessive noise. Thus, an “iso-annoyance” chart was presented so that trades between these variables could be assessed, or judgements made as to where best to invest in improvements.

5.4 Natural Light

Dr Kjeld Johnsen, of the Danish Building Research Institute, described his work on natural light and the responses of people to different intensities and qualities of light, working in laboratories and in the field, looking at different building types, design and layouts and various window designs, blinds and glazing colours. He reported that daylight is preferred to artificial light and research evidence shows that light interacts with humans and affects performance, health and psychological comfort levels. Experiments were described where offices were zoned into three areas and satisfaction levels were reported, the highest levels being for those nearest the windows. It was found that this effect was mediated by the number of people in the room, the greater the number the more pronounced the negative effect of being away from the window. Further, despite issues with glare, where possible people chose to place their computer screen near a window, rationalising this by saying that they liked to see out. One of the main messages from the presentation was the need to design buildings from the inside out, tailoring the building to the people's needs and activities, so that these become part of the architecture.

5.5 Artificial Light

Dr Martine Knoop, from Philips lighting and the University of Technology Eindhoven, continued from this suggesting that although natural light may be preferable to most we can not always access it and thus the need for artificial light that is sympathetic to our human needs. She described how research into both the visual and emotional effects of artificial light is well developed, but the area of the biological effects less so. Her work is in this area, looking at the mechanisms behind the relatively recently discovered receptor in the retina, with a connection to the suprachiasmatic nucleus, that is linked not to perceptions but to biorhythms that affect for example our alertness levels through the day and night. Knowledge of the effect of light on these circadian rhythms can be used to help those working night shifts, with jet lag, seasonal depression and also Alzheimer's patients whose sleeping patterns may be disrupted. So for example, for night workers a strong white light, with a wave length between 446-474 nm, may be used to suppress the production of the sleep hormone melatonin with the effect of increasing alertness and a shifting of the circadian rhythm. Work has also been done using cool lights for alertness and warmer lights for relaxation. This has been for example introduced in a primary school in Manchester, where cool lights give way over the lunch period to warmer lights for relaxation before switching again to cool lights to re-energise pupils for afternoon activity.

The area of the effect of coloured lights, that cause similar effects with lower brightness, and might be more energy efficient than white lights, is still being researched. There is a degree of complexity operating here as from psychological research blue light is shown to be relaxing, whilst the warmer red light to be activating, however photo-biological research shows that cool white light activates whereas warm white light relaxes.

5.6 Planting

Dr Philip James of the University of Salford described the effect of plants on our well-being. He gave statistics on the growing problem of mental health problems that the World Health Organisation predict will run second only to heart disease by 2020. The personal costs of this are inestimable but the economic costs are thought to range between £21-90 million a year in the UK, depending on whether employment costs are included or just medical care. Various items of research evidence were cited to show the influence of the natural environment on issues of health and well-being, such as mental health, stress related illness and surgery recovery time. It was pointed out that the Royal Commission on Environmental Pollution calls for the natural environment to be placed at the heart of urban design, regeneration and management.

Studies have shown that in windowless rooms containing plants workers were 12% more efficient, their systolic blood pressure was 1-4 units lower and they had a self reported 10% rise in attentiveness. Plants then can be seen to have a positive effect on the working environment, absorbing carbon dioxide, producing oxygen as well as binding dust agents, which is beneficial to health. Further, they help to create a live atmosphere and promote well-being. Their study raises questions of how designs for buildings can use the outside environment to enhance our interior spaces.

5.7 Overview of dynamics

The various presentations on discrete sense dimensions highlighted a recurrent theme around the dynamics of the experiences involved. This was in two ways: the changing nature of human needs over time (whether within a day or over years); and the complex interactive effects between the various sense experiences, both physiologically and socially driven. Another recurrent theme was that of “naturalness”. Examples of these themes from the presentations are:

- For colour, the curvilinear issue of avoiding over or under stimulation and the importance of difference and balance, mediated to some extent by natural expectations, eg dark below and light above.
- Related to air quality, the varying decay curves for the perception of different smells depending on their natural source or otherwise.
- Taking natural light, the battle between the natural desire to be close to the window versus the problem of glare (with the former often winning!) played out in social settings where the number of people and their positions in a room make a significant difference.
- In acoustics related to performance, the interaction between the space and the performer, as well as the audience, in terms of “playing the room”.
- The case of artificial lighting, that can tap into natural circadian rhythms with powerful impacts on involuntary emotions, complicated by the quite counter-intuitive effects of various coloured lights.
- Planting, that is bringing the natural environment indoors, with powerful impacts on mental processing, but also related social interactive opportunities too.
- At the interface of comfort in relation to heat and noise, the notion of curvilinear iso-annoyance curves across which the utility of possible improvement actions could be judged.

Linking back to the framing perspectives of Section 4, it would seem that humans do have characteristics derived from our evolutionary roots and these are likely to underlie the recurrent impact of dimensions of nature. The complexity is rooted in the fact that spaces are, in practice experienced by individuals holistically and interactively. At a base level this is confounded by the cognitive limits of humans, so

that perception becomes an “ill-posed question”, in which the brain endeavours to represent reality probabilistically, as best it can. This capacity varies over a life time, generating different needs at different times. This practical complexity is compounded by the psychological and sociological layers of issues associated with spaces, such as status, control and social belonging. Alongside all of this is the dynamic human “design” tendency to imagine, experience and reflect on spaces, so progressively seeking better solutions.

The overall message from the excellent work reported is that finding optimal solutions is not a simple search for *the* answer. It is, rather, a subtle process of addressing multiple aspects and moving towards a better understanding of the questions we need to address. Elegant solutions can then more confidently be derived at the dynamic interface of spaces and individuals over time.

Against this challenging background the workshop participants split into groups around specific types of space.

6 Summary of Group Work on Issues / Solutions (Sessions 6, 7, 8 and 9)

A keyword summary of the problems and issues felt to be pivotal to each user group is given in the second column of Table 5 below, along with the neuroscience-led responses, in terms of actionable solutions in the third column. There is a large range of factors here, the columns are not designed to link horizontally and the meanings of the phrases are somewhat coded. The paragraphs following provide summaries.

Table 5: Users’ Problem Issues and Actionable Solutions

User	Users’ problem issues	Actionable solutions
Schools	Learning – how to	Make learning addictive, meaningful, positively
	Empower – ownership	Design and plan age-related learning
	Truancy – attract	Link schools to street corner / home – focus on 30-35 yr olds
	Control – bullying	Use age appropriate
	Wider social impacts	Involve children in design stage
		Let knowledge inform strategy
Housing	Safety	Designing for life phases
	Identity and preciousness	Designing for identity and our experiences
	Future-proofing education	Home ownership and pride of place
	Home and well-being	Sense of community
	Integration	Lack of identity
	Inflicting buildings on people	Environment / brain changes / behaviour
Retail	Isolation	
	Density	Neurosciences as a testing instrument
	Differences from surroundings / outside	Physiological
	Variations within the building	Link between neuroscience and actual behaviour
	Social image	Lighting, temperature, ambience
	How to make things attractive	Navigation, identity, space,
Offices	Environmental impacts / pollution	Break the race track
	Control	Define briefs clearly
	Ownership of my space and stability	Negotiate ownership of space
	Gradation from private to public spaces	Create psychological / neuro-scientifically meaningful spaces
	Internal and external environmental quality	Neuroscience as an assessment tool
	Messages to clients and employees	Uncover hidden factors

6.1 Schools

In order to influence design the schools group felt that there needs to be better definition of the knowledge base to provide a clearer understanding of the elements that are most critical to well-being. They saw problems related to the individual learning experience and it was felt that designs needed to respond to the different approaches, for example, individual work researching on computers compared with taught lessons. Designs need to support these different approaches with spaces that are fitted to them. Creating a sense of ownership was seen as important, but there was felt to be a problem in engendering this feeling owing to the limited degree to which space can be personalised. However, it was felt that a sense of empowerment and ownership might reduce problems of vandalism by pupils. Another problem was that of truancy and it was felt that school design should work to make the space seem attractive or 'cool' for pupils. One participant cited a school in Australia that had countered problems of high truancy levels from children escaping to a shopping complex by relocating within that complex! However there might be problems in refreshing novel solutions and making them sustainable. The issue of control was felt to be problematic, and this included how design could be used to create safer environments and reduce issues such as bullying. This could also assist on health related issues, for example an alarming statistic cited was that 75% of the pupils in City of Manchester schools do not visit the toilet throughout the whole school day. The last area that was felt to be important was that of drawing the extended community into the schools so that the lines between the learning environment and the outside were less rigidly demarked.

The neuroscience response to these issues focused on an awareness of the need for age-appropriate design and for positive reinforcement of the learning experience, making it 'an addictive' experience. The importance of age in relation to the acquisition of certain skills was showed in relation to language where neurones for this gradually disappear if not used by the age of three years and continue to gradually reduce thereafter from the age of seven. In terms of school design this could have implications for aspects such as acoustics. A final response was to introduce designs that linked schools more to their community, enhancing an overlap between the two.

6.2 Housing

The housing group was concerned with safety, such that design can make people feel and be safer within their homes. Another issue was that of identity, related to a notion of greater user involvement in design ideas and briefing rather than having a building 'inflicted' on occupants. But, this went further to ask how design could reinforce notions of 'preciousness' and identity? Linked to this was the idea that DIY building skills are needed to adapt, modify and personalise these spaces to make them homes and questions were raised about whether there was a loss of the required skill base for this. Another aspect was the need to more fully understand the effect of the design of home spaces on health and well-being, including aspects such as garden spaces. The issue of isolation and how design can help integrate people within a community was also seen as important. The social context of housing also occurred with a focus on issues such as the mix of public and private buildings and the quality of the urban environment. Consideration of these aspects were seen as potential means towards social cohesiveness and counteracting feelings of isolation.

The neuroscience response focused on the need for design to reinforce or accommodate our own sense of identity, but that also there was a need for housing

design to be flexible to fit the different life-stages, thus to accommodate different and changing needs. These two issues are interrelated, so for example young children move from their “primary repertoire” developed during embryonic life to build up experience and also acquire language. In the development of this “secondary repertoire”, possessions and precious things are pivotal to the process. Dispositions are affected by these early experiences that condition subsequent responses working on associations from memory. This might help to explain our often safe and traditional selection of building design, an aspect that is reinforced by the financing systems for houses that display a general unwillingness to take risks on novel forms.

Older people, and those suffering memory loss in conditions such as Alzheimer’s disease, have similarities with the child where these early possessions and early learnt skills, such as playing a musical instrument, are a retained and vital, if frail, means of coping with their environment. However there might be a need to introduce a little more stimulation within design for the 25-50 year age group, although even here radical responses are unlikely to be found satisfactory.

6.3 Retail

The retail group saw congestion, with peak periods of demand through the store as problematic. This problem can start right from the car park, through to entrances and then to aisles themselves and checkouts. This issue raises questions about the positioning and density of goods on display. The notion of attractive design and ambience was also an objective, both to create different particularised zones within the store, and as a means to showcase goods. However certain designs for this had caused problems with the flow of customers through the store and this disrupted their desire for an efficient trip. Variations within the building were quite a large problem. For example, areas surrounding chiller units made the air temperature quite cold and this contrasted sharply with other areas. Further the contrast between the external environment and the inside of stores was often felt to be profound, especially for light and temperature levels in the winter months. Community issues and the impact of stores on their neighbourhood, including environmental impacts such as light pollution to the surrounding area, were also discussed. The social image of retail stores was also raised, for example in relation to feelings of security both in and around units. This included aspects such as accessibility, not just the physically, but also psychologically, given the way certain shops can feel intimidating to people. Generally it was felt that the aim within design should be to optimise the sensory experience and reduce the discomfort experienced, and that this needed a greater understanding of the relationship between factors such as comfort, feelings of contact with nature and sales.

Neuroscience provided insights into areas such as way-finding and navigation that might help to improve congestion issues. For example, by careful design that taps into all three methods that the brain uses to navigate around spaces in a complementary fashion. These are, reading and interpreting signs, remembering routes and using the brain’s mapping system. In practical terms, horizon lines have been shown to have a large role in assisting with orientation and this is often obscured in stores. The brain also finds high levels of symmetry hard to cope with when navigating. However, neuroscience also suggests that people find it unpleasant if they feel they are being forced down a given route in a “race track” channel. In relation to memory, brain monitors can detect at the time of telling whether a person will remember something, this is something that they are not aware of themselves and cannot self report. This might be a way of helping to determine which designs are useful and can help the retention of information.

6.4 Offices

From the offices group the issue of ownership again occurred. The concern centred on control issues within space and the messages it gave to others about its occupant. The need for some control encompassed issues of territoriality and the notion of 'my space' that includes associated needs such as for privacy. Alongside this were ideas about the messages that these spaces give to others, such as to other employees about status within the work environment and to outside bodies such as clients. The appearance of workspace can, and is, used for marketing. The gradation from private to public spaces was also discussed. Problems of both internal and external environmental quality in workplaces were identified.

Responses to these centred on the need to create psychologically meaningful areas, while at the same time supporting workers' functional needs. More focused research is needed to gain a fuller understanding of how workers use their spaces and how to help them learn how to get the most from their building. The balance between the spaces given to individuals and communal areas, in terms of size, location and uses was also discussed. Offices should be dynamic environments which encourage user-space interaction in order to support work. Increasing mobility of workers means that communications technology and workspace need to be planned and implemented together in order for the environment to be fully supportive to work. Neuroscience research suggests that it is possible to create space that is in tune with our brain's capabilities, so that spaces are psychologically meaningful as well as supportive. Preliminary studies indicate that a neuroscientific approach to assessing space may provide a new layer of knowledge that complements studies to date, which are based largely on users' assessment of their surroundings. On a more general note this group highlighted the importance of the briefing (programming) process itself as a mechanism through which users' needs can be identified and prioritised, potential conflicts negotiated, and shared meaning created.

7 Summary of Group Work on Key Actions / Research (Session 10, 11 and 12)

New designer-led groups took the above ideas and worked to identify high leverage action areas which could provide an immediate focus for progress, together with longer term research questions that could underpin future progress. The groups' outcomes are summarised in Table 6. As before the columns are not designed to link horizontally.

Table 6: High Leverage Actions and Research Themes

User	High leverage actions	Research themes
Schools	Define current knowledge base and implement	Can we better define the desired knowledge to influence design?
	Design schools to be part of the urban fabric	What aspects of the school environment contribute to attaining well-being?
Housing	Make homes more enjoyable	How to optimise the connections between community, developer, land and Government?
	Engender pride, identity, DIY, confidence, handcraft	What are the implications of the concept of happiness?
Retail	Make lighting arrangements flexible	What is the relationship between observed behaviour and neural mechanisms?
	Optimise the absence of discomfort	What is the relationship between comfort, access to nature, sales and price?
Offices	Learn to use the building	How can spaces modify the brain / mind?
	Realise that working space is a space, not a building	What is the optimal balance between individual and communal spaces?

There is a mix of items, but some emphases can be identified within and between the actions and research themes. The high leverage actions in the second column tend to focus on the individual user's interaction with their space, trying to move to a position where discomfort is avoided and current possibilities are optimised. Contrasting to a degree, the research themes in the third column emphasise:

- wider connections, to include communal spaces and community interactions;
- aspirational levels of experience, concerning happiness and well-being, and;
- a deeper, research-based, understanding of the causal connections between aspects of space and behaviour, linked to a range of activities.

8 Conclusions (Sessions 13 and 14)

This section is in two parts. First a summary of the agenda for action emerging from the workshop and then initial consideration of the potential next steps the group can take to further this agenda.

8.1 Agenda for action

The workshop and especially the group sessions succeeded in identifying the existence of strong common themes across all of the user types, but with necessary variations in detail and emphasis, of course, within the areas of schools, housing, retail and offices.

Looking broadly the elements of an agenda for action can be divided into three parts: responding to user needs, the knowledge base regarding impacts of spaces on behaviour, and process issues concerning the co-production of design.

The particular aspects of *“responding to user needs”* highlighted by the workshop were:

- Age dependency issues
- Identity and personalisation aspects
- Wellbeing-health
- Ownership
- Navigation
- Learning
- Belonging and community

Within these areas there are some polar views, for example, the idea of design working to meet very specific needs and the view of ‘mainstreaming’ that holds that good design will be able to accommodate diverse special requirements. Another such is the idea of the personalisation of space reinforcing identity aspects, whilst also accommodating and incorporating the wider needs of the society / community. From neuroscience comes the need to accommodate specific ages and for design to be sensitive to experiences that build up our secondary repertoire (as opposed to the primary repertoire coded by the neurones that are developed during embryonic development). Design then should work towards accommodating and reinforcing individual experience in relation to their particular age dimensions.

The particular aspects of the *“knowledge base regarding impacts of spaces on behaviour”* highlighted by the workshop were:

- The need for a better definition of the knowledge base to help improve design drawing from neuroscience, psychology, sociology and physiology.
- The need for greater understanding of the relationship between design choices and behaviour.
- The ethical aspects of how this knowledge might be used to manipulate people.

Each of the user groups had their own specific target research problems. For example for schools, the need was to uncover those aspects of the built environment that are critical to attainment and the implications for design.

The particular aspects of “*process issues concerning the co-production of design*” highlighted by the workshop were:

- The involvement of users in the design as an iterative process, moving from the ‘inside’ responding to needs through mechanisms such as briefing /consultation and to the ‘outside’ where the building is seen as an entity. Further to discover from users whether their needs have been met. It as felt that these processes should have an element of serendipity, so that the place of chance is acknowledged within the design process.
- The evidence base should lead to informing design policy and strategy for example in terms guidelines and norms.

Each of the use areas has different stakeholders and operates in a variety of markets. How user consultation can be arranged and policy guidance given will be very dependent on these variations. However, it is believed that the potential for the creation of better spaces that are more positively used and enjoyed can be enhanced by more effective interaction with all types users.

Figure 2 shows the main foci for action diagrammatically, stressing the interactions between all of the parts.

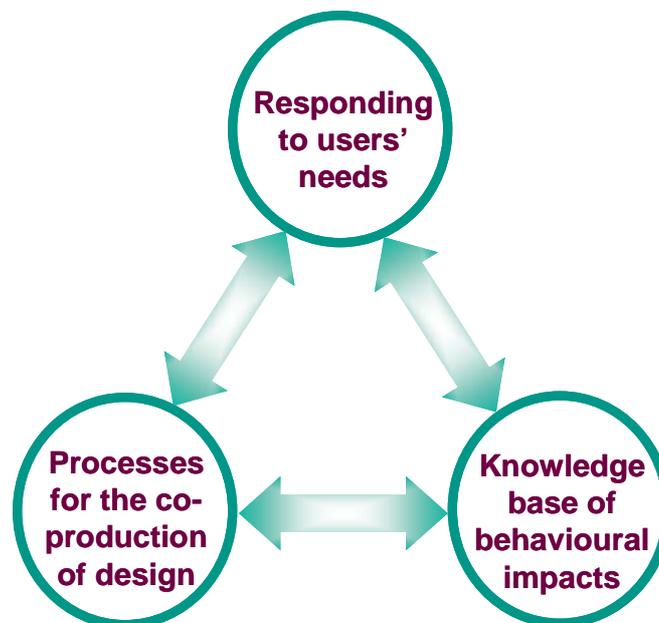


Figure 2: Agenda for action – linked foci

8.2 Next Steps

Of course a report cannot hope to capture the depth of the expertise present in the participants or the richness of the discussions that took place. So, further collaboration is key to making real progress. There was a strong consensus that the momentum created by the workshop should be built upon and various mechanisms were discussed.

- Feedback from the attendees was requested regarding the workshop itself and potential avenues of development.
 - This was done and a lot of responses have been received. They are very positive about the stimulating environment created by the mix of people present and several note significant shifts in their individual thinking as a result of the event. Several wish to take specific aspects forward.
- A summary report of the workshop will be produced.
 - This is it in draft, but it will be finalised pending feedback from participants.
- A range of bilateral connections were created and joint activities are likely to follow from these.
 - Some of these were mentioned in the feedback and informally. Where possible it would be good to capture these when tangible progress is made.
- Several of the user representatives indicated their willingness to be involved in “play and test” activities.
 - These could be one-off or part of bigger projects – see below.
- Opportunities to obtain press coverage and to influence policy consultations were mentioned.
 - These are in hand, but it would be helpful to feedback progress when available. This affected at least the TES and the Financial Times.
 - A two page summary of the neuro-science insights on variations by age follows as a supplemental report from John Eberhard.
- Possible project bids could be prepared with, for example, opportunities emerging in Framework Programme 7 of the EC.
 - There is a preliminary network invitation that the SBS work could link to and this is being investigated.
- A future meeting is possible, but would be more beneficial when some joint activities have taken place to drive such an event with fresh experience.

There is clearly great potential in the SBS area and it is hoped that we will all try to translate this into actions with strong practical and / or theoretical impacts.

Appendix: Neuroscience insights on variations by age

Supplemental report by John P. Eberhard, April 2007

A child's brain also goes through "critical" periods of construction. The largest part of the construction process of the new brain occurs in the early life of the fetus. During this early stage, the basic structure of the brain is created and the sensory organs form their basic connections along the nerve pathways. This is all done from the genetic encoding of nerve cells and biological processes that guide the construction provided by DNA we inherit from our parents (this encoding is like blueprints for a building).

The human body and brain are composed of cells. Each cell contains membranes, a cytoskeleton, organelles, mitochondria, and a nucleus that contains our genes. These cells are formed over the 40 weeks of gestation by the embryo. As the human body takes shape in the womb, populations of cells enter different streams of development: one is destined to give rise to the lungs, another to muscle, a third to the kidneys and bladder, etc. DNA provides instructions for forming proteins from amino acids. Some proteins are structural while others are enzymes made within the factory.

During the third week of life as an embryo, the first structure for the brain begins to form. It continues to develop over the next eight months as cells are generated by the division of progenitors (popularly called stem cells) that migrate into position and begin forming networks by connecting with other neurons. There is no master plan or central processor involved; it just happens as the nervous system organizes its own intricate structure.

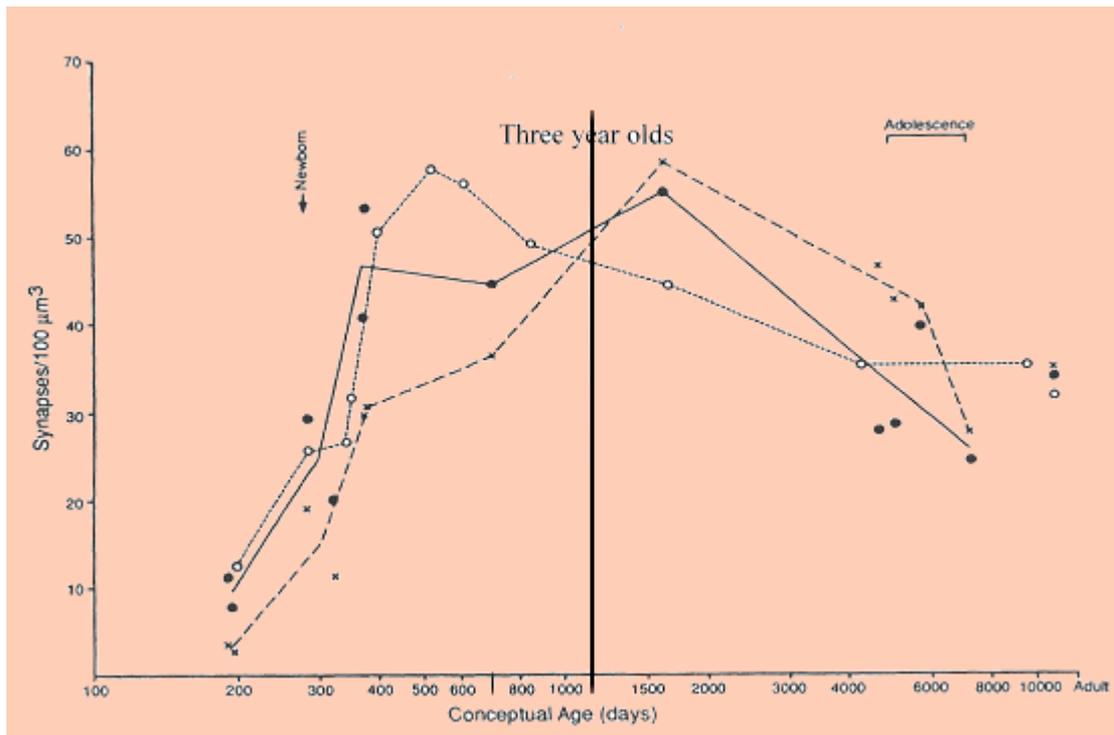
The sensory systems of the human fetus develop in a predetermined sequence. Four of them, including touch, pain, position, and temperature sensitivity are the first to appear. Shortly after this, the "vestibular modalities" – the sensory systems of the middle ear that detect motion and determine balance – are installed. Next come the chemosensory systems of smell and taste. All of these systems are well established during the third to sixth month of fetal life. During the sixth to ninth month in the womb the construction of the brain enters a critical stage, first for the auditory cortex (hearing) and then for the visual cortex (sight). The development process continues once a child is born, adding and subtracting neural networks based on experiencing the world.

If a child is born prematurely, at six or seven months, the critical development processes for hearing and sight can be disrupted by being exposed too early to noise and light in the neonatal nursery. These systems will be forced to begin working prematurely. As Dr. Stanley Graven (1992) has reported in his study of neonatal units, this does not result in a child being born either deaf or blind, but they lose their acuity. This is a good example of how knowledge from neuroscience can provide evidence-based design criteria for building spaces.

The early brain and development

The brain we use as adults to remember the past is a different brain than the one that stored memories when we were children. The chart shown below (from the *New Cognitive Neurosciences*, page 85) shows the mean synaptic density in three areas of the brain at various ages:

- In the auditory cortex – filled circles
- The calcarine (sulcus on both sides of which lies the visual cortex) – open circles
- The Prefrontal cortex – Xs



This chart is the result of having powerful brain imaging methods to study aspects of the physiology of sensory and language processing in humans. Event-related brain potentials (ERPs) are voltage fluctuations in the EEF (Electroencephalogram - a method of brain scanning) in response to a controlled stimulus. The ERPs essentially show the number of synapses in the neuronal populations that are recruited during the processing of the stimulus. The chart shows the dramatic changes in synaptic populations during the first two years of life when “pruning” of unused synapses occurs. As Prof Joan Stiles says in her summary of these changes:

“Brain development is a complex and protracted process. It begins at 28 days post-conception (in the embryo) and continues into adulthood. Both biology and experience play critical roles in shaping the final organization of the brain. Development is more than a simple unfolding of a predetermined genetic plan. While genes are critically important for brain development, the development process is also adaptive. It is the interaction of biological systems with each other and with input from the world (such as experiences with life) that ultimately determines brain organization and function.” Quoted in Rita Carter’s *“Mapping the Mind”*. Page 22

We also remember how to walk and talk – both of which we learned before we were three – because these are procedural memories, not episodic memories