Passive architecture based multi-sensory development of indoor environments

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ABSTRACT - Senses have been an important aspect in the experience of architecture. The active incorporation of the senses have changed through time and different styles in architecture. The aim of this thesis is to reconsider the role of senses in the perception, appreciation of the indoor environment and determination of atmospheres. The leading question of this research will be: 'How can we facilitate a multi-sensory perception for an embodied experience of architecture?'. Therefore the human senses, the reclassification of senses and the dominance of the visual experience are investigated, within time, thought and particular interpretations of architecture. It discusses how senses are interpreted in Western culture, the loss of reality and humanity of architecture, in relation to space and atmosphere. Among the sensory perception, it also addresses climatic issues that influence the human sensation of architectural environments. The division of tasks within the building process alienated the architect from the climate design and technological progresses enabled this aspect to be determinant in the design of buildings and atmosphere. In order to establish a standard for thermal comfortability, generally applicable for higher productivity, a global comfort database of occupant surveys is set that resulted from diverse researches in sterile laboratories. The invention of mechanical climate regulation for a comfortable and predictable indoor climate diminished a human, multi-sensory experience. Whereas the historical precedents of vernacular building inhabited these characteristics seen in the cultural and symbolic qualities that emerged from the environmental condition. Finally, this research proposes a reinterpretation of the historical background of the area Parkstad, Limburg. The notable historical developments that influenced the economical growth of the area stem from the Roman era and the late mine industry, of which both traces are vanished off the map.

Keywords: senses, experience, perception, atmosphere, indoor environment, ocular-centric, multi-sensory design, vernacular architecture

INTRODUCTION

In the contemporary architectural discourse, architecture is expected to be reactive and adaptive considering changing climatic circumstances that elaborates on our senses and our comfort, for building smart. One can consider the reaction, adaption and experience within architecture in two ways. The first one is a more contemporary interpretation, which relies on technological developments that enables architecture or architectural elements to react on changing circumstances and provide stable or comfortable indoor climate. The second one considers architecture and the creation of atmosphere as an outcome of a collaboration of reaction, adaption and experience for a multi-sensory design. The second one - where tools for architecture are mastered by the designer seeks for interaction between the built environment and the senses of the body for appreciation - intersects with the urge to incorporate senses in architecture for a sophisticated experience of a building. The urge arises from the shift towards a ocular-centric code of culture that occurred in time, developing itself from classical Greek philosophy and Western culture on to Modernism (Kerr, 2013; Pallasmaa, 1996; Plato, 2011). The five sensory aspects were all of importance for the experience of architecture, but during the Renaissance the visual aspect became privileged, and implications of the Industrial Revolution on building technologies and processes reinforced this aspect. The phenomenon got strengthened through time and the conditions of

our contemporary society, where we live in such a rush that we almost forgot how we perceive occurrences and phenomena in our daily life.

The domination of the visual perception, additionally the division of tasks within the building process alienated the architect from the realization of the projects and final appearance. I believe that the distantiation from the project, deminishes the experience and unity. Considering the architect as an outsider of the context and their unawareness about local techniques and climate solution that developed throughout the history. Thereby subcontracting of particular processes breaks the unity in architecture. The addition of multiple installations for a better or predictable indoor climate diminishes a more human, multi-sensory experience and whereas it could have additional value for the experience if it was a starting point.

The main question that guides this research is:

"*How can we facilitate a multi-sensory perception for an embodied experience of architecture?*"

Subquestions that define the line of the research:

"*How can architecture become an art of reconciliation between ourselves and the world through our senses?*"

"*How do we perceive architectural environments?*"

"*What is the relationship between the scientific architectural method and the devices of technology as they have been applied to determine the atmosphere in buildings?*"

BACKGROUND

The objectives for the graduation project are to incorporate a research of the architecture of senses into the design and a reinterpretation of the landscape. Among the sensory perception, this thesis will address climatic issues that influence the human sensation of architectural environments. While aiming for multi-sensory architecture, its association with the local identity and its minimal use of energy.

Taking into consideration the mentioned objective, this thesis proposes a reinterpretation of the historical background of the area Parkstad, Limburg. The notable historical developments that influenced the economical growth of the area stem from the Roman era and the late mine industry, of which both traces are vanished off the map.

The 'Via Belgica' was a mainly ancient military and trade route that connected the northern part of the Roman Empire from Boulogne sur Mer to Koln. In the contemporary condition the interpretation of the road is divided among different countries: France, Belgium, the Netherlands and Germany and is hardly recognizable. The route crosses Parkstad Limburg and dissects varying urban areas and landscapes (Limburg, 2005).

(fig. 1. (Limburg, 2005, p. 9))

The potential of this area as cultural heritage and link to the communal roman history is still to be explored. The increasing interest for ancient cultures and new visions for the restructuring of Parkstad Limburg provides us an opportunity to make the history of the area visible and accessible by incorporation. The municipality aims for a visual connection between remnants and the route (Gerritsen et al., 2009; van der Valk, Delheij, Klinkers, Demandt, & Ouarani, 2009). Nevertheless considering the excellent atmospheres of Roman architectural objects the restriction to visual aspects will remain inferior. The city Heerlen inhabits remnants of a Roman architecture, which is still exposed as the Roman Thermae of Corriovallum and oldest building of the Netherlands.

The most recent historical layer of Parkstad is related to the mine industry. The area is known for and has extensively benefitted from its fertile grounds and its rich substrate. The former arcadian landscape and agriculture transformed rapidly into an industrial landscape during 1900 and 1950. Infrastructural changes were necessary to achieve an effective management for coal mining. Simultaneously the demographics of the area changed with the first batch of mine workers from the Netherlands followed by foreign migrants. Even though the area flourished rapidly, the expansion was regulated by a societal vision,

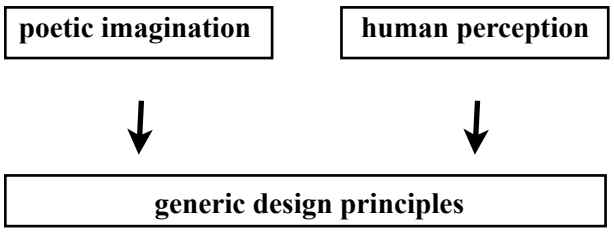
incorporating the migration flow in mine colonies and absorbing into the social mainstream. Nonetheless the identity of the area became common with mining activities, and a strong social cohesion emerged in the working class. The closing of the mines from 1965 on strongly affected the socio-economic situation until nowadays, the migration excess made place for shrinkage in economic growth and demographic variety (Beckers et al., 2015; Gerritsen et al., 2009). The release of the mining industry and demolishment of industrial heritage vanished the recent character of the area, and nowadays Parkstad is regretting the absence of the shared identity (Beckers et al., 2015). I think the representation and experience of both historical layers should be reconsidered or reinterpreted for the contemporary society. Since both phenomena drastically changed the structure and composition of the area and made it a centre point for trades and its further developments.

METHOD

The research started with a careful investigation of architectural theory about the perception of architecture and its change through time and philosophy. These served to understand the formation of our ocular-centric code of culture, the architecture belonging to that culture and the sacrifice of multi-sensory architecture. In the first chapter 'Defining architectural perception' this subject will be elaborated.

After the description of architectural perception according to architectural and philosophical theory, an attempt will be made at answering the research questions and finding and explanation for the experiences as observed in literature and experienced by my self. In order to find a generally applicable theory of experience. To achieve this ambition the poetical, imaginative experience of architecture and the human perception will be investigated in order to explain the experiences and emotional reactions in the literature to provide an opportunity for predetermination.

The third chapter tries to explain the experience of architecture that is mostly influenced by the interior and the indoor climate through the evolution of the well tempered environment. Therefore the evolution of installations will be introduced shortly, followed by the definition of conventional standards for working spaces, such as the International Organization of Standardization. Looking towards our contemporary conception of pleasurable climatic conditions the adaptive climate comes forward, which can be explained in terms of vernacular architecture and alliesthesia. With these findings, an attempt will be made at a general theory of architectural experience that is constructed with elements such as material, light, vapour and air quality.

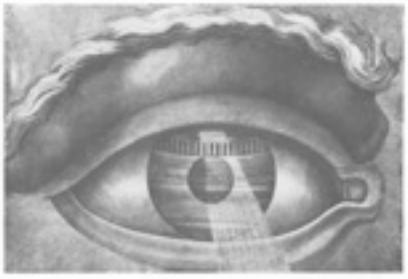


(fig. 2. own ill.)

RESULTS

DEFINING ARCHITECTURAL PERCEPTION

In the Western culture the visual is considered as real and objective, what you see is what exists and interpretation is restricted. So certainly, classical philosophy was based also on vision and visibility. The use of ocular metaphors in the Greek thought, for clarity, reliability and thrust strengthen their position that knowledge, truth an reality are related to visibility (Pallasmaa, 1996, pp. 6-7). The remaining senses are more private and subjective for this thought, therefore inferior to vision. Within architecture the ocular-centric paradigm commenced with the optical corrections in the construction of early Greek temples and the elaboration on decoration, images engraved in the structures, trying to narrate a story or history. Since the Greek thought is particularly accepted by the Western culture, we can also question if perception is constructed and experienced differently in particular societies and periods, and not merely a cognitive process in an individual's brain (Howes, 2005). Either a elaboration of both aspects.



(fig. 3. Architecture as an art for the eye. *Eye Reflecting the Interior of the Theatre of Besancon*, engraving after Claude- Nicolas Ledoux. (1784))

Although there was a focus on the perception of the visual, the five sensory aspects were all of importance for the experience of buildings, especially the sacred buildings, but during the Renaissance the visual aspect became privileged. In this time frame the senses were considered as a hierarchical system from vision down to touch, correlated to elements of the cosmic body:

'...vision was correlated to fire and light, hearing to air, smell to vapour, taste to water, and touch to earth...'

(Steven Pack in (Pallasmaa, 1996, p. 7))

The elemental understanding was inherent to the constitution of the theory of knowledge and investigation on the nature of being (Howes, 2005, p. 324), which were fundamental subjects for the thought of that era. As in the ancient Greek philosophy the reason was based on vision and visibility, in the Renaissance the association of vision with reasoning became entrenched again. The vulnerability of vision was recognized by Descartes, even though he considered the sense of vision as the noblest in his objectifying philosophy, but he was aware of the perversive capability of the eye. Therefore the sense of touch was a privileged experience that was considered to be more definite, since the interaction between the object and the body is more intimate and exact (Pallasmaa, 1996).

Architecture was considered to be part of this holistic thought, involved in this enquiry of the nature of being, human existence, its expression and interpretation of human's existence (Pallasmaa, 1996; Pevsner, 1970). The visualization of society and space that followed from the rationalization of society engaged architecture in this debate. Metaphysical questions that architecture was trying to touch were, the position of the individual in the world, time, life, eternity and sacrality. Again the implementation was focussed on visual perception, trying to mimic our position and relativity to the world. The tendency of the Western thought and culture that admired the objectivity of the eye is brought further to our time, supported by the evolution of reproduction techniques and developments in technology. The major technological invention that started off the production and reproduction of thought and images was printing (Carpo, 2011; Virilio, 1997). An alternation started from the oral culture to the visual, the print slowly commenced superseding the conveyance of information and expression of sound by multiplications of writings. There was no more need to take physically part of a community in order to become informed, engaged in a debate, or express your ideas and findings. Once the dominance of sound and the oral tradition got conquered, cohesion and the physical participation lost its importance, other sensory experiences accompanied by convergence of people in particular amounts, atmospheres and spaces loosed its intensity and intimacy. We can argue that the shift towards an ocular-centric culture reclassified the senses in an hierarchical order starting from vision, and aided the separation and alienation of the remaining senses, by bringing the world closer to us. This restricted multi-sensory experiences of the body in society from this point on. So far this is the effect of developing a method for reproduction of printing, many more tools and machines are developed that have changed the landscape, city, dwellings, lifestyle, economy, wealth and our notion time and space (Harvey, 1985, 1989; Lefebvre, 1996).

In our contemporary society we reached a point of saturation in means of the ability to produce and reproduce mechanically and digitally structures that certainly affected the plasticity of architecture and its materials and components. The traditional construction methods and organic materials, significantly based on a particular topography, the capabilities of the body to pleasure the muscular, haptic senses rather than to pleasure the eye, lose their prominence by implementation of fabricated and finished items. Even the execution of intimate spaces such as our home became part of this lifeless, almost effortless construction. Whereas traditionally this process is guided and limited by our body, the way it moves, lifts, stacks and assembles, which leads the creation through a multi-sensory design process. As if the bird shapes her nest by tasting and conveying material in her bill and shapes her sculpture by the movement of the body (Bachelard, 1994, pp. 90-104). The cities have become increasingly a production of the eye, alienated from our remaining senses and removed from the body by its scale, accessibility, the inhumane rapid movement on site and in the air or the gaze on top of its skyscrapers.The city and its inhabitants have loosed the experiential depth and have become spectators of a theatre called "life". We have been caught by

'...the distant realm of vision.'

(Pallasmaa, 1996, p. 20).

The way we think we experience a city, place or atmosphere has been restricted significantly, that we can achieve a simultaneous experience, as if we have visited the place through our computers and the data we can also derive from the internet (Virilio, 1997). At this level the object is completely isolated from its context and climatic circumstances. We can barely observe the image, our perception becomes formulated by an interpretation of an interpretation. The technological developments furthered the tendency of the weakness of our sensory perception, which becomes more and more incapable to comply certainty and a sense of reality (Kerr, 2013). Since the senses enable interaction with the world and our surroundings the notion on senses within the architectural design process have to remain preliminary. Architecture is one tool to encourage and remind us of the participation of other senses for our perception of the world. The phenomenologists architects, Steven Holl, Juhani Pallasmaa and Perez-Gomez (2006) tried to explain the question on perception within architecture by defining phenomenal zones. The conditions of light and shadow, and the haptic realm were conceived fundamentally, believing that:

'The perceptual spirit and metaphysical strength of architecture are driven by the quality of light and shadow shaped solids and voids, opacities, transparencies, and translucencies... What the eyes see and the senses feel in question of architecture are formed according to conditions of light and shadow.'

(Holl et al., 2006, p. 63).

Various interpretations of the sun as a light or heating source adds a quality of temporality and use to architecture as it is changing through seasons and during day, which makes architecture more humane, honest and real. Still the phenomenological approach seems too restricted to visual qualities of light. Although the senses in architecture are also conditioned by indoor environmental parameters such as, thermal, indoor air and sound perceptions. Nevertheless Zumthor circumscription to enhance atmosphere by materiality and detail keeps room for the manipulation of these environmental parameters (Holl et al., 2006; Zumthor, 2012). I believe that it is important to mention the conception of atmosphere, that is defined by our perception of space in architecture. In architecture,

'atmosphere is an immediate form of physical perception, and is recognized through emotional sensibility'

(Wikipedia, 2015).

The material imagination is thought to be influential in the emotional sensibility mentioned afore. According to Bachelard (1994), these images project deeper and more intense experiences than formal images, because the experience of material is constituted by a multi-sensory perception that incorporates at least the perception of vision, touch and hearing perhaps. At this point I agree with Pallasmaa that acts of recollection, recognition and comparison constituted by a multi-sensory experience are essential for an embodied memory and image of a place, space or atmosphere (Pallasmaa, 2006). Either very personal and diverse, which makes the experience of an atmosphere slightly particular for everyone.

The acts formulated by Zumthor (2012), Bachelard (1994) and Pallasmaa (1996) for an embodied memory and image require time to be processed and performed within architecture. Therefore time has to slow down primarily their perception and the movement of bodies. To achieve this ambition a deceleration of sensation and the notion on temporality by means of material expression and cyclic changes are considered essential. In order to achieve an experience that enables the improvement of our sensational experiences, architecture needs to be experienced plastic, tactile and intimate rather than clear and predictable, which is advocated widely in the last decennia. The reaction we receive from buildings such as collection and amplification of the sound we produce, the adaption of temperature or smell to our presence or the involvement of motion leads us towards an interaction with the building that reminds us of our presence and participation in a building, used a metaphor for our being in the world. The built environment mediates our understanding and perception of permanence and change, our position, and participation in the culture of *'Building, Dwelling and Thinking'* (Heidegger, 1986). A particular language for the communication of this message does not exist in architecture, each context, situation, case or object has to be approached separately to provide its specific and original experience. The only motives are the conception of temporality that can be materialized and designed, the collaboration on

an embodied memory or image and the physical perception of predictable sensations.

HUMAN PERCEPTION

Our senses facilitate us the experience, which is considered equally for every healthy person. Simultaneously it enables an interpretation of the perceived information through interaction with individual parameters, which is capable to control or protect our bodies of external influences. The human adaptability system stemming from the perception and control mechanisms has enabled the survival of human kind, and health, comfort and pleasure for people in different climates (Bluyssen, 2009; Dahl, 2010). The architectural idealism and the forthcoming regulation of indoor climate of the modernist era ignored this essential aspect which was persistent in existing local architecture.

> *'Indoor climate, is the technical term for the climate created by the house's physical enclosure and the various climate systems employed'*
>
> (Dahl, 2010, p. 23).

The acceptability of the indoor climate quality is influenced by the satisfaction of at least 80% of the users and assuring the healthiness of the occupant. This implies that the climate is evaluated neutral if it satisfies the majority, we do not speak of comfort or thermal pleasure yet. The ultimate indoor climate imagines positive well-being, comfort, pleasure and essentially a variety of sensory stimulations (Bluyssen, 2009; Dahl, 2010; Kaplan, 1995). According to Olgyay (1963) the study of the variables in climate, biology and technology are essential for architectural perception, thus must be interlocked within the search for an architectural expression.

(fig. 4. Interlocking fields of climate balance (Olgyay, 1963, p. 13))

Therefore this chapter investigates the human perception of the indoor environment, by looking at the mechanisms in our body that receive and process the information. Considering the feeling of senses in questions of architecture are created according to the conditions of indoor environment and the biology of human.

In essence the human senses constitutes our perception for a comprehensible internal imagination of the environment. The information of environment gathered by our senses is conveyed via nerves to the brain to be processed and a prescribed action is send to a particular and relevant part of the body (Bluyssen, 2009; Levine, 2005). Thus the sensory system consists of sensory organs or receptors, neural pathways and partially the brain. The senses we consciously control are sight, hearing, smell, taste and touch since we are able to observe and control these. Their communality is the sensitivity to a particular stimulus, and the location of the receptor cells at a receiving membrane of surface (Bluyssen, 2009; Wikipedia, n.d.-b). The sensory receptors transforms the environmental energy into an electrical action potential that convey the input to the brain via nerves. This process is called transduction. The nerve fibres carrying the signal to a specific location in the brain, according to the specific location in the cortex the brain knows the kind of information is send (Levine, 2005; Steinberg, 2002; Wikipedia, n.d.-b). The information can contain pain, touch, cold, smell, noise and sight that are transformed by the mechano-receptor, thermo-receptor, chemo-receptor, noiciceptor and photoreceptor (Bluyssen, 2009). The following response from the perceived and processed information occur in consciously and unconsciously behaviour.

The experiences of our body are regulated, controlled and produced by the nervous, endocrine and the immune system, where the brain is responsible for the regulation of the activities. The immune system controls our body in relation to the environmental parameters, whereas more abstract conceptions such as emotion and perception are controlled by our limbic system and the central nervous system. The endocrine system enables to regulate stimuli by both our immune and limbic system (Bluyssen, 2009). The nervous system is mainly responsible for the input and output of information. This system includes sensory and motor functions as well as instinctive and learned

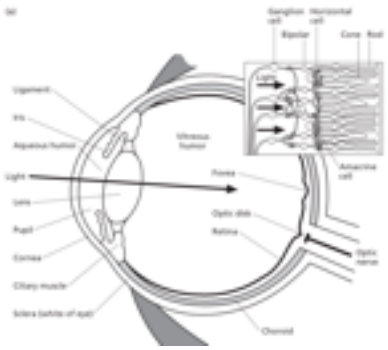
behaviour. The information is transducted to the brain via nerves, unlike the endocrine system that uses blood vessels for conduction of information that causes longer lasting effects. The endocrine glands release the hormones directly into the blood at different locations of the body. The hormones bind with available receptors to regulate our function, send messages and act on them (Bluyssen, 2009; Wikipedia, n.d.-a). There are three control mechanisms to discharge the body of hormones. The simple hormone regulation, where predetermined and set limits affect the hormone secretion. The complex hormonal regulation where the activity of a gland is controlled by the hormones of another gland. Finally the complex neurohormonal regulation, where an interaction between brain and the endocrine system takes place through environmental factors. Light, sound, temperature and odour in combination with brain activities exert control over the endocrine system and hormone secretions over the neuron system via target glands. At least, the immune system does consist of a number of protection mechanisms against diseases. The layers of the protection mechanism starts with physical barriers, the natural or innate immune system and finally the acquired or adaptive immune system (Bluyssen, 2009).

MEASURING THE RECEPTION AND PERCEPTION OF THE HUMAN BODY

The particular conditions in similar environments people are exposed to are visible in the manifestation of common complaints. The sensitivity towards the quality of the condition or a specific source is seen in the commonness of the symptoms. These can be detected in body fluids, the pervasiveness in symptoms by exposure and through investigations of mental activities (Bluyssen, 2009; Frumkin, 2001). In the following our sensual perception will be investigated by description of the sensation, the mechanism and the thresholds.

The human skin is the greatest part of our body that is exposed to environmental conditions, containing a number of active and passive functions. The passive functions embrace the protection of body against external environments. The prevention of penetration by micro-organisms and biologically active materials, the secretion of sweat and the five sensation belong to the active functions located all over the body. Although we expect that the human body can resist the presence of a stimulus to a certain extent, the adaptation to pressure and thermal sensation is able to reduce, discharge the actual sensation and increase the threshold during continuous exposure (Dahl, 2010). The pain sense, nociceptors on contrary are not adaptable to stimuli. The sensation of temperature is either peculiar, it consists of cold and warm receptors separately. The cold sensation does respond to cold and warm idem, it neither shows a response to a mechanical system. The sensitivity of a cold receptor ranges from approximately 15 °C to 34 °C and warm from 38 °C to 43 °C (Bluyssen, 2009). The sensation of the skin is controlled by the thermal balance mechanism, as the term balance is indicating this mechanism searches an equilibrium between the heat transmission and the heat production. Either the body has a thermal storage capacity that is able to compensate temporary production and losses in the body temperature. The thermal storage capacity enables the adaptation of thermal sensation and increases the thresholds (Bluyssen, 2009; Olgyay, 1963).

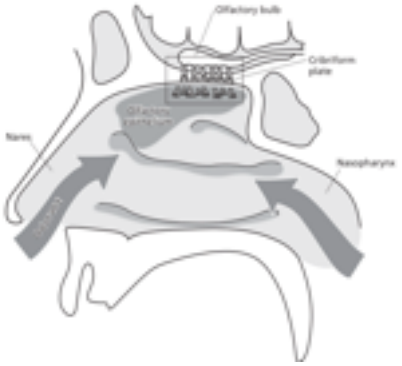
The eye is the sensation that is described foremost in the perception of architectural environments, since it is considered as the real perception for humankind. Here again we look at mechanism and adaptation of thresholds. The eyeball consists of two pieces, the smaller frontal segment, called cornea that is linked to a large segment sclera. The eye exists of three layers from inside out these are the retina, the vascular tunic and the fibrous tunic. The light falls in the eye through the pupil on the cornea afterwards in the lens, a flexible body surrounded by bodies that absorb partially the light, which is conveyed to the retina. The retina is light-sensitive layer, that receives the light and transforms it into chemical energy that is transmitted via the optic nerve paths, and accordingly to the sensitive cortexes of the brain. Here the neural energy becomes perception (Bluyssen, 2009; Frishman, 2005).



(fig. 5. Cross-sectional diagram of the human eye (Frishman, 2005, p. 54))

The retina has two types of receptors, rods and cones. The rods communicate sight and the cones fill in the colour by wavelength discrimination. In the dark and at low light levels the activity of the retina is from the rods, these mediate vision that indicate shapes of what is not clearly illuminated by light. Whereas the cones are active under photopic conditions, higher energy levels. These are sensitive to brightness and wavelengths that determine the colour in vision. Although the cones are not as active as rods they are capable to adapt to certain conditions. Their sensitivity increases within five minutes, while the rods need ten minutes to adapt and determine the sensitivity of the entire eye (Bluyssen, 2009; Frishman, 2005). Certainly the eye needs time to adapt and determine the information, thus when the visual stimuli is replicated to rapidly, the perceived vision is a flicker. Again the eye has a quality that can adapt itself to this condition, if it occurs at a certain speed within equal intervals, this is also an unconscious sensation where the subject is unaware of the changing illumination. Actually this is how movies are being recorded, the frames are placed in such a way that we perceive it as fluent recordings whereas it consists of multiple images ordered within a specific interval. The sensitivity of the eye and the sensation differ still at higher and lower energy levels, one needs sixty flashes per second, the other four flashes per second to reach this critical fusion frequency.

The indoor air quality is perceived regardless and intensive by the nose. The perception of smell is processed via the olfactory system, nevertheless a smell is already perceived odorous through the volatility and solubility of the the chemical features in the mucus covering the olfactory receptor cells. Considering the tasks of the nose: warming up and filtering particles of the air we breath, only a certain amount or type of air pollutants can reach, thus activate the olfactory epithelium in the nasal cavity (Bluyssen, 2009; Cowart & Rawson, 2005). The olfactory epithelium consists of 10 to 25 million receptors cells on a surface area of 3 to 5 cm2. The cells that end in a swollen bulb are connected to the brain by the fibre tract and the other component of the bulb, the axons linked with different brain centers together form the olfactory brain. The interpretation of the signals by the olfactory brain is associated with preceding experiences of odour, that distinguishes the quality of air. The intensity and irritation of odour depends eventually on the olfactory adaptation (Bluyssen, 2009). Similar to the adaptation of light it is difficult to determine thresholds or model the intensity and irritation of the air quality, even individual thresholds are unreliable (Cowart & Rawson, 2005).

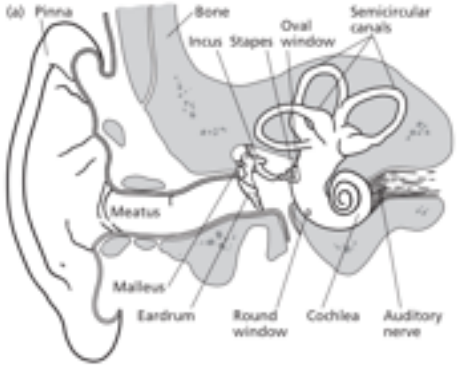


(fig. 6. Diagram showing nasal activity (Cowart & Rawson, 2005, p. 570))

The constant exposition to a particular intensity of odour will easily reduce in time and will be more tolerable, although mixtures can resist more than single compounds of odour. Recovering from the smell will occur within a minute after the odour is discharged and can occur even faster than the recognition of the odour.

In the design process the acoustics of architecture are calculated and modified later on, unless it inhabits a program in the building. Unfortunately the general conception about sounds in a building are evaluated disturbing, especially in working conditions. Although we see certainly that architects master and take into consideration the amplification of sound in the environment, of the visitors and the installations (Hawkes, 2008). The perception of the sound takes place through the ear via the sense of hearing. Although the human ear consists of two different senses: the sense of hearing and of equilibrium. The sensory organs of hearing and equilibrium belong to one component of the ear, which is the inner ear, together with the external and middle ear it forms the human ear (Bluyssen, 2009). Similar to the smell of scent, during hearing sound or noise that is directed to the eardrum is limited and transformed by absorption and reflection. The sequence is as follows: the pinna, the ear shell modifies and transmits the sound to the auditory canal, this causes the eardrum to vibrate, consequently the ossicles transmit the vibrations through the middle ear in order to transfer vibrations to the fluids in the cochlea. The middle air discriminates, transforms and improves vibrations while reducing the amount of reflection,

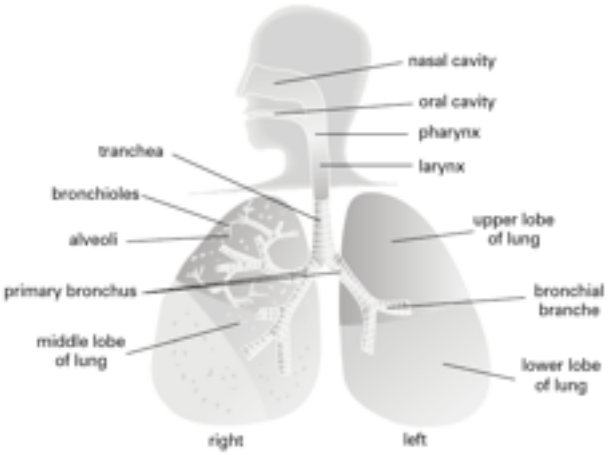
therefore most determinant in the perception of sound.



(fig. 7. Structure of the peripheral auditory system showing the outer, middle and inner ear (Moore, 2005, p. 386))

Still the ear is sensitive to a particular interval of the produced sound, with some flexibility depending on person. The sound that is perceived is communicated with its number of cycles per second, the frequency that is expressed units of Hertz. The interval of the sensitivity covers 20 Hz to 20.000 Hz, while the most accurate sensation is perceived with middle frequencies from 500 Hz to 5.000 Hz (Bluyssen, 2009; Moore, 2005). The auditory sense is more sensitive to higher frequencies, and the equilibrium sense to low frequencies. The equilibrium organ functions separately from hearing and is activated by velocity of movement and rotation of the body. The vibration thresholds vary largely, it is hard to predict a pleasurable sensation. These are determined by mechanical aspects and human factors. Similar to the previously described sensations the frequency, intensity and duration of the exposure affect the perception and its bearability (Bluyssen, 2009). Nevertheless overexposure of single intense sound or repeated exposures can cause severe or permanent damage.

The sense of taste is not remarkably in the indoor architectural environment, although we can argue the respiration of chemical features that can stimulate our gustatory sense organs since we exhaust or breath through our mouth. Nevertheless in neutral climates it is hardly recognizable that such an intensity of particles is available which can be detected by our sense of taste. Unlike other neural systems the chemical senses of smell and taste are not fixed, it changes in time (Lawless, 2005). Although the respiratory tract for the study of indoor environments seems more applicable. The respiratory tract enable the process of respiration that transports oxygen from the outside air to the cells within the organs of the body and carbon dioxide in the reverse direction. The components of this process are the upper and lower airway system. The upper embraces the nose and paranasal cavities and partially the oral. The lower airway system includes the trachea, the primary bronchi and the ducts in the lungs.



(fig. 8. The respiratory tract, upper and lower airways system (Bluyssen, 2009, p. 40)

The diaphragm is the acknowledged muscle for breathing, along with other muscles. The activity of breathing is directed rhythmically from the hindbrain, which can affect or disturb the pattern by the receptors of the respiratory muscles. The receptors are triggered by rapid lung inflation and a set of chemicals (Bluyssen, 2009).

DEFINING COMFORT: EVOLUTION OF THE INDOOR CLIMATE

In the previous sections elements of architecture, its material, form and imagination constituted the ingredients for the architectural experience, although the technics constituted by mechanical system are left aside. Together these aspects and acts of imagination constitute technics for the poetic ends in architecture composition (Hawkes, 2008). Nevertheless the development of mechanical systems for heating, ventilation and lightning led to development of new stylistic approaches and technical applications widely applicable. The historical development of the emerging mechanical systems in the built environment is defined by Reyner (1984) in three manners of control: the Conservative, the Selective and Regenerative (Reyner, 1984). The conservative mode of management is most clearly expressed in a statement of Sir John Soane (1753-1837), “see the

fire, or no degree of heat will satisfy" (in Wilmert 1993 (Hawkes, 2008)), in other terms even though the building is warmed by mechanical systems the image of warming remains important for our feeling and comfort. Still the technics were responsibly implemented for a qualitative experience considering the poetic ends of their environmental imagination. The selective environment, regularly applied in more humid and tropical areas, allows particularly the penetration of desirable environmental conditions from outside and preserves a desirable climate inside. Nowadays this mode of management of indoor environment is widely applied in adaptive climates, where the building is capable to make use of desirable environment outside and adapt its architectural appearance. Lastly the regenerative model which bears the least natural characteristics, it makes use of mechanical and high energy-consuming systems that are dimensioned according to extreme values of the coldest night and hottest day. It is widely applied in the seventies in office buildings, the poetics of the architectural compositions became subservient to the technics and spatial demands of this mode (Dahl, 2010; Hawkes, 2008; Reyner, 1984).

Hawkes (2008) elaborates his theory about environmental imagination by his own experience of architecture. While he tries to answer the relationship between the scientific method and the devices of technology, the way they altogether determine the atmosphere in architecture. Similar to criticism about the industrial revolution and the distantiation of people from the final product he accuses the eruption of unity and sub-contraction of the building process for the loss of complexity in culture. Still he believes that some architects succeed in this act by incorporating arts and crafts in their architectural conception. The term arts and crafts already indicates the importance to master the historical development of building and building processes. The historical precedents of vernacular building especially the cultural and symbolic qualities that emerged from the environmental condition has to remain part of the conception and realization of the built environment. These are essential to understand the relation between culture and environment, it provides elementary experiences of space in accordance with principles of nature and the climate (Dahl, 2010; Hawkes, 2008; Rapoport, 2006). The five experiences provide us the perception of sight, hearing, touch, smell and taste, altogether a holistic approach to climate design, which I consider as multi-sensory design. The precedents in vernacular architecture and the sensory perception of our surroundings constitute altogether a significant source of inspiration for designing a variety of climates for the stimulation of our sensations that support the perception of architecture (Dahl, 2010).

Scarpa is presented successfully in the reinterpretation and acknowledgement of the previous relationships constituted by preliminary designs. Whereas Zumthor's particular projects shows his capability to predict the simultaneity of shape and material, in coexistence with the qualities of the local climate, certainly that it embraces and enforces the purpose and atmosphere of its function and meaning.

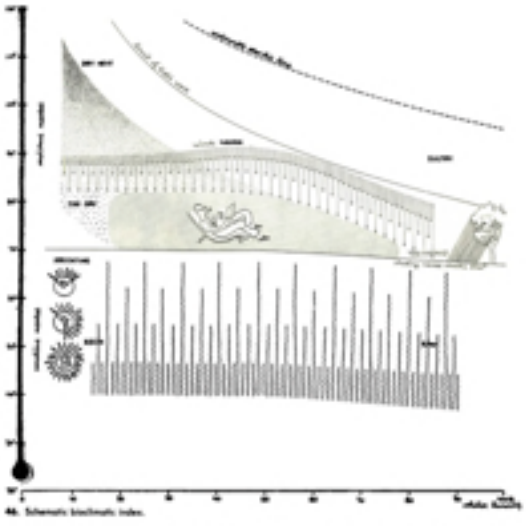
(fig. 9. Zumthor, Protective Housing for Roman Excavations, Chur, Graubünden, Switzerland, 1986 source:http://www.pritzkerprize.com/2009/works)

Although Hawkes (2008) advocates to answer the determination of atmospheres or environments in architecture, he sticks to a description of his personal experience that is immeasurable and subjective. The elucidation of his architectural perception is inconvertible to standards applicable in general nor scientifically reliable. The specific architectural perception seems too complex to convert to standards, although an attempt to express comfort sounds more reliable. Certainly the recognition of comfort involves a range of sensations, which are constituted emotionally and intellectually besides the physical perception. Thus, we recognize comfort subconsciously if we experience it, it is impossible to ensure people experience comfort equally (Rybczynski, 1986). However attempts for dimensioning the ideal state of the indoor environment for especially working environments are based on the absence of discomfort, average values and satisfaction of

majority of the occupants. The comfort zone defined by Olgyay (1963) in terms of

'Physical and physiological reactions result from this struggle for biological equilibrium. Man strives for the point at which minimum expenditure of energy is needed to adjust himself to his environment'

(Olgyay, 1963, pp. 14-15).



(fig. 10. Bioclimatic chart (Olgyay, 1963, p. 23))

The traditional parameters of comfort are air temperature and air's relative humidity, the relation of both factors is and adjustments to achieve comfort are represented in a graphic. Ole Fanger (1970) an indoor climate researcher extended the amount of parameters for the definition of comfort he,

'defined the comfort concept by means of six measurable factors: air temperature, radiation temperature, air movement, relative humidity, metabolism or energy conservation and the thermal qualities of clothing. Subsequently, measures have been added to air pollution, quantity of light and limits related to the acoustic environment'

(Fanger in (Dahl, 2010, p. 28)).

The American Society of Heating, Refrigerating and Conditioning Engineers, ASHRAE is one global comfort database of occupant surveys that resulted from diverse researches in sterile laboratories and the International Organization of Standardization, which defines ergonomics of the thermal environment in ISO 7730. Both present methods for prediction of thermal sensation and exclusion of discomfort using calculations of PVM (predicted mean vote) and PPD (predicted percentage of satisfied) (Kurvers & Leijten, 2013; Standardization, 2005). The comfort is indicated by the satisfaction of 80% of the occupants. Although this research was mainly based on working conditions in specifically office buildings, regardless of the time spend besides the work, outside the office and timeframe or season. The ideal condition for the highest performance of the white collars is thought to be found, and applied to architecture and interiors from the seventies to nowadays. The standards of the global comfort database are adapted by the many national organizations for standardization in building regulations and the International Organization for Standardization. While the continuous exposure of the workers to the ideal condition is not fully recharged, similar to the adaptation of our senses, an adaptation of the performance takes place instead of an acceleration. The adaptation to a stable climate leads to zero thermoregulatory effort of the body either insensitivity of the thermo-receptors, which results in thermal boredom that weaken the perception of changes day by day (Candido & de Dear, 2012; Dahl, 2010; de Dear, 2010). Therefore only mechanically controlled systems lead to dissatisfaction among the users if they are unable to adjust the climate to their individual needs and prevailing outside temperature (Kurvers & Leijten, 2013). The regenerative mode of environmental management Reyner (1984) identifies, is applicable to this method of climate regulation, which bears the least of nature, is high-energy consuming and is experienced dull and monotonous.

The popularity of high-energy consuming buildings is decreasing considering the climatic changes caused by emission of carbon dioxide, consequently the scarcity of fossil fuels, and dependence on finite sources. Inherent to this process an efflorescence the adaptive climate takes place. The introduction of thermal alliesthesia advocates the beneficial effects of thermal variety and its pleasure instead of neutrality that can be achieved by adaptive climate regulation, which is in turn less energy consuming and more exciting. The ground for these statements about adaptive climates and thermal alliesthesia, can be explained among other things with the biophilia hypothesis (de Dear, 2010). The term embraces human's intrinsic fascination with life and life-like processes. Life-like processes of in the environment are clearly visible in seasonal changes, organisms adapt them selves and their lifestyle to these changes. People feel affiliated

with nature and being able to observe and notify this make people comfortable and more or less *'a body of nature'* (Wilson, 2013). Nonetheless the biophilia hypothesis suggests that we have an instinctive bond with other living systems and life-like processes. Whether on beforehand the importance of physiology in architecture and the multi-sensory design are advocated extensively.

DISCUSSION

In the Western society we spend most of our time in enclosed spaces, a working person spends approximately 90% of his day indoors that increases getting elderly. The indoor climate becomes the most dominant climate we perceive, therefore the quality and variety is significant considering the decreasing time we spend in natural environments. This already indicates a simulation or interpretation of the perception in natural environments for indoor environmental control. The natural environment on contrary to our fully equipped shelters, contains a wide range of atmospheres during day and specific location whereas we try to establish a neutral and stable climate for our working and living conditions with the aid of new technologies. Hence certain amount of energy and research are put together to investigate the ideal state of comfort, and constitute a global data set for the indoor climate. Nevertheless, even if we try to express the perception in measurable units there is a constant interaction between scientific measurements and psychological means, which is less certain. The non-physical aspects: emotional and intellectual sensations are neglected, in the search to the ideal state of comfort.

However, the maintenance of thermal comfort according to the global data sets have certainly aided the productivity of the occupants in modernist buildings. The notion is set on modernist building, since this tradition of building devastated significance of local architecture and its simultaneous climate regulation, emerged throughout the history of entire societies. In this thesis I mention the significance of vernacular architectural precedents often, one may question if the principles are still applicable to the needs of the changing and densifying society. Although simple implications such as climate and season adaptive approaches in the global data set, and the possibility of individual operation can provide a wider variety of climates, excitement and satisfaction. Thus a sustainable and satisfactory indoor environment will require firstly changes in behaviour and expectation.

CONCLUSION

Designing an experience every individual equally senses is not predictable as it is advocated by early indoor environment researchers. Certainly the sensation is constituted with either immeasurable and measurable parameters, which indicates some room for manipulation of the general experience. Considering the validity of the general experience some indoor environmental parameters can be defined: thermal, lightning, indoor air and sound. Each of them can be manipulated by architectural composition and its material properties that can be expressed in measurable results. The indoor environment parameters are most of the time elaborated and adapted to vernacular building throughout history. The cultural and symbolic qualities that emerged from the environmental condition has to be taken into consideration. When thinking about the history of building and architecture we recognize there was no way of mechanical climate regulation until the 19th Century. In essence all architecture was passive and designed according to bioclimatic design principles, based on the local climate. These principles include: natural ventilation, direct solar gain and thermal mass. These three principles embrace the four indoor environmental parameters: thermal, lightning, indoor air and sound, which are perceived through the sensory organs elucidated in the section Human Perception. The main conclusion of the research is that we have to revert our conception of comfort constituted by high energy consuming buildings to the conception of comfort established by principles of passive architecture and bioclimatic design emerging from the interconnection of cultural, symbolic and local climate exchange. This approach to architecture and human being facilitates a new approach to physiological, biological and climatically conscious architecture, and considering that climate and comfort vary in time and space from neutral conditions to thresholds. Again through sensual awareness in the indoor climates and the adaptive capacity of our bodies architecture becomes a reconciliation between human and the world through our sensations. To bring this into practice environmental imagination is significantly, for the interconnection of architectural perception and devices of technology that determine the conception of atmosphere.

EPILOGUE

Starting this study about my fascination of multi-sensory design I believed that in the end I probably end with a matrix of material, scale and dimensions of architectural components, which could be applied to various contexts. In the end we see that there is actually no new method to design architecture or define atmospheres, on contrary we recognize again the strength and importance of our historical predecessors. As if these were constructed out of the cultural and symbolic qualities that emerged of environmental conditions, again it becomes important to master qualities and constitute an environmental imagination. Although the word imagination suggests an act that is obtained personally, it is more about prediction of architectural interventions and the climatic implications of the compositions ranging from material expression to presence of your body.

In the context of Parkstad, whom history dates back to the Roman empire I believe that there is a lot to learn about historical buildings, typology and building processes. Considering the subject of this research, the multi-sensory design approach I decided to do a reinterpretation of the Roman Baths that once were located at the heart of the city. For my experience baths facilitate a wide range of different atmospheres that are perceived either physical either emotional. I believe that I have done a research so far that can support the physical perception I will try to address, but either the emotional sensitivity by addressing the common past and the shared identity of the area and the inhabitants. The most recent history of the area that is vanished of the map and sight is the mine industry. Bringing together the multi-sensory experience of the Baths and the mine industry an interesting contradiction appears. Whereas the baths always functioned as entertainment and sanitary facility, the mines where associated with heavy and intensive labour and dirt. Both of them have their specific sensory aspects which can be mentioned or acknowledged in the environmental imagination of the building. The thermal energy from the underground in the mining districts, nowadays used for central heating, the sound of the activities performed and amplified underground. The vibrations absorbed by the body. Nevertheless the contradiction of the silent, intimate and clean atmosphere of the bath constitutes a wide range of different sensory experiences, which I aimed for the design of a building.

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