

A sustainable design approach for the built environment based on the principles of Anthropological circadian rhythms, Chronobiology and Chronopharmacology

Manohar Balasubramaniam, Anil Pawade and Kundan Bharambe

Professors, D.Y.Patil College of Architecture, Nerul, Navi Mumbai.

Corresponding Author: Manohar Balasubramaniam

ABSTRACT.

Our present approach to architectural design is cosmetic. We are more obsessed with visual impact and less with needs and functions. Our design manifestations are nothing but a celebration of technology. The spaces we create have no soul. We try to justify them after they have been created. This paper calls for a paradigm shift in the way we approach our design interventions. Our spaces should be created based on the activities we are supposed to perform in them. Our activities should be based on circadian rhythms and chronobiology. Tangibly and intangibly our main source of energy is the sun. Our entire biological clock is synergetic with the earth's orbit and the position of the earth relative to the sun. A correlation matrix is sought to be established between the position of the earth, human circadian rhythms, chronobiology, proposed activities and climate. It is argued that if our architectural expressions are evolved based on scientific processes they would be more relevant and meaningful. The various ways in which this can be achieved is briefly discussed and presented. The advantages of this approach are briefly enumerated. It is also ensured that all the proposed solutions are sustainable, co friendly and have the least impact on the environment.

Key words. : Circadian rhythms and chronobiology.

Date of Submission: 28-01-2020

Date Of Acceptance: 11-02-2020

I. INTRODUCTION

Architecture is based on the principle that Anthropos or Humans are the centre of concern and all design concepts and manifestations should be focused towards this goal. Ergonomics, Anthropometrics and Ekistics were some of the sciences developed with this objective. These sciences have done their bit and continue to address the physical comforts of humans. Physical comforts are the tangible aspects. The critical fact which seems to have been missed out is that humans are not creatures of logic-they are creatures of emotion. Unless they are emotionally happy they can never appreciate physical comforts. Our design interventions should focus on these intangible aspects for the solutions to be accepted, appreciated and implemented. To implement this we need to understand the basic fundamentals of circadian rhythms and chronobiology.

Importance of circadian rhythms

The importance of this study can be illustrated by the fact that the Nobel Prize in Physiology for the year 2017 was jointly awarded to Jeffrey C. Hall, Michael Rosbash and Michael W. Young for their discoveries of molecular mechanisms controlling the circadian rhythm.

Refer to the following image no-1 for the press notification.

The Nobel Prize in Physiology or Medicine 2017



Image 1- The three scientists who were awarded the Nobel prize for their study on circadian rhythms.

Source.:<https://www.fens.org/Global/Pages/News/2017%20Nobel%20Prize.png>

The relevance of Chronobiology

Chronobiology is the study of life with relation to time. This science was conceived by a renowned French astronomer Jean Jacques d'Ortous de Mairan in the eighteenth century.

Renowned scientists like Wilhelm Pfeffer, Erwin Bünning, Karl von Frisch, Jürgen Aschoff, Colin Pittendrigh and Arthur Winfree took this science forward in the twentieth century.

All points on the earth's surface are subject to a day-night cycle. This happens because the earth revolves around the sun and also rotates about its axis. Solar radiation has two components –Heat and light. This heat is the chief source of energy for the biotic and abiotic components of the earth. Presence of heat and absence of heat defines seasons. All living organisms on our planet are influenced by this presence of light (day) and absence of light (night).

The human body is one big biological clock and this clock in turn is governed by a set of clocks. Each component of the human body is governed by its own clock-the hunger cycle, the bowel cycle and all other allied cycles. The ecosystem is very fragile and intricate. Each component is a closed system with its own dedicated clock. Within the human body they exchange matter and energy to function as an open system. A proportionate combination of all these systems together form the human body which in turn is an isolated system. This makes every human being on this planet unique because there is a variance in their body response to heat and light.

Homeostasis and physiology

Homeostasis is the process by which every organism on our planet seeks to adapt and adopt to its immediate environs to ensure its proclivity and survival. Physiology is the study of various body functions which aid this process.

Anthropological Rhythms

The four main biological rhythms which govern our existence are ultradian, circadian, infradian and circannual. Ultradian rhythms are less than 24 (twenty four) hours and deal with basic rest and activity cycles. Infradian rhythms are greater than 24 (twenty four) hours and deal with events like bird migration, monthly menstrual cycles and hibernation in animals. Circadian rhythms are a 24 (twenty four) hours cycle and deal with sleep-awake episodes. Circannual cycles deal with annual events like breeding cycles.

Solar radiation

The energy from the sun reaches the earth in the form of solar radiation. This radiation has two components –heat and light. The quantum and intensity of both these parameters keep varying throughout the day. It is this heat and light which governs our basic circadian rhythms.

Chronobiology deals with the variations in these variables with relation to time.

Anthropological drawbacks

Human have three basic drawbacks compared to all other creatures which inhabit our planet. The first is that they cannot negotiate climate and weather without PPE (Personal protection equipment) or clothes. The level of clothing required is based on a factor known as “clo” value which ranges from 0 (zero)-A state of no clothing to 4.5 (Four point five)-Arctic clothing. In fact humans are always clothed from the time they are born to the time they die. The second drawback is that they cannot see in the dark-they have a very poor and limited vision. They are therefore completely dependent on light for their mobility, movements and existence. The third is to be thermally comfortable they spend almost 80 % (Eighty per cent) of their time indoors. All their mobility is also between indoor spaces- for e.g. House to office and back.

The concept of circadian rhythms

The human body operates like a self regulatory clock with a sleep –wake up cycle of about 24 (twenty four) hours. The earth revolves around its own axis at the rate of 15 degrees per hour. Therefore the time taken to execute one complete revolution is 360 degrees/15 degrees per hour which is approximately 24 (twenty four) hours. As this rotation of the earth is anti-clockwise its initial cardinal position with respect to the sun is East (Dawn) and its final cardinal position with respect to the sun is west (Dusk).

The earth here is a dependent variable and the sun is an independent variable. This relative position of the earth with respect to the sun traces a path which is approximately a figure of eight and also called as the analemma.

Most Life forms on the planet is primarily dependent on this small window between dawn and dusk for survival, existence and procreation. Humans are no different. If we can align our activities in consonance with the sun we can truly be sustainable.

Decoding the human clock

The following image no-2 illustrates the various facets of the human biological clock.

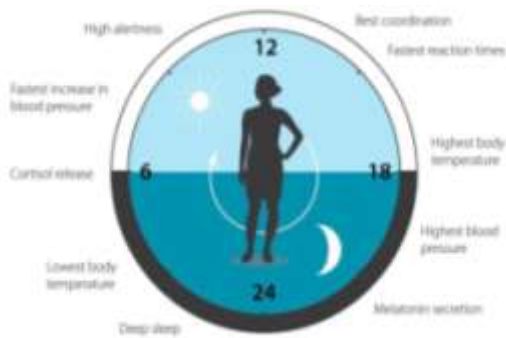


Image2- An image indicating the intricate relationship between sun, moon and the human body.

Source.:<https://zjff683hopnivfq5d12xaooxr-wpengine.netdna-ssl.com/wp-content/uploads/sites/2/2018/05/circadian.jpg>

From the above image it is evident that in a twenty four hour day cycle the most active and productive period for humans is between 0900hrs and 1500hrs when the sun is at its peak. It also illustrates the importance of sleep in the human context. 12 (Twelve) hours of rest is absolutely essential to be really productive 6 (six) hours during the day.

The role of hormones and steroids.

Hormones are signalling molecules which set things in motion. The sleep-wake cycle in humans is regulated by a hormone called Melatonin. Cortisol is the main stress hormone. Both these hormones play a key role in regulating the balance of our body. Cortisol is secreted during the day and melatonin is secreted during the night. The following image no-3 illustrates this cycle.

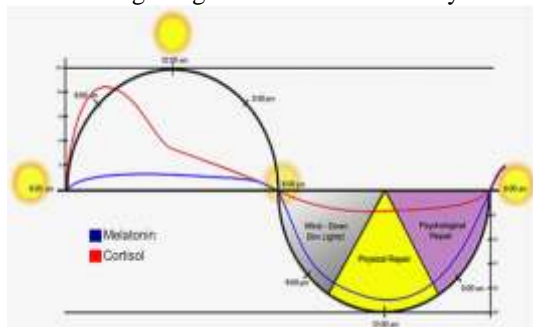


Image 3- A diagram illustrating the chrono cycle of melatonin and cortisol.

Source:
<https://jennifermundy.files.wordpress.com/2015/12/sleeplight2.png?w=640>

Steroids is a biologically active organic compound .this is artificially created to replicate hormones .it should be judiciously used and its misuse has long term health effects.

Architectural manifestation

The human existence centres on the solar radiation. This radiation governs the secretion of essential hormones in our body. The quality and quantity of this solar radiation varies throughout the day depending upon the position of the earth in relation to the sun. Aligning our activities and designing our spaces in consonance with this rhythm will ensure a truly sustainable quality of life.

Importance of light

Light is that component of EMR (electromagnetic radiation) which excites the retina and creates an image. The quantum and quality of natural light plays an important role in human psychology. Artificial light is consistent, uniform and monotonous and can never match up with the qualitative aspect of natural light. Directly ingesting natural light and ensuring solar flushing in all our spaces will ensure thermal and psychological comfort. Natural light also plays an important role in connecting our indoor and outdoor spaces. Our entire existence is shaped by natural light and natural ventilation. Our design interventions should manifest this importance.

Incubating a natural light ecosystem

Ingress of the right amount of natural light at the right time and at the right place should be the guiding principle of any architectural design. Light wells, light tubes, fibre optics and all other allied features should be incorporated to harness light and transfer it inside the interior space. Appropriate fenestrations to ensure maximum possible coverage of internal spaces should be the main focus of any design intervention. Light has a therapeutic effect and invokes the appropriate circadian rhythms in our body.

Importance of materials

Materiality plays a very integral part in creating a desirable ambience in any space. Light can be absorbed, reflected or transmitted from a surface depending on the finish of the surface and the quality of material. Natural materials add a special quality to the light and hence are a preferred choice for surface finishes. All the biotic and abiotic components of this universe act as light filters. The interplay of light and shadow creates the drama of nature. The appropriate materials and surface finishes play a very important role in incubating the right ecosystem.

Revolving and evolving facades

The façade is the interface between the inside and the outside space. It acts as a regulator for climate and weather. If the weather is warm it

helps keep the inner space cool and if the weather is cool it helps keep the inner space warm. It needs to be conceived as a thermally sensitive façade. It should aid and abet the entry of the requisite amount of solar radiation into any space.

The façade should revolve in consonance with the position of the earth with respect to the sun. It should also evolve at the same time to filter and admit the requisite amount of solar radiation. The filters used should be bio filters.

Quality index of a space

The light ingress into a particular space defines the quality of the space. Absence of light is darkness. The architectural intervention into a space must ensure adequate, uniform and desirable distribution of light. Solar radiation has two components –heat and light. Both of them need to be regulated depending on the time of the day and season. When this is synchronised with circadian rhythms the quality of the space would be at its best. Light is a very powerful pulse generator. If light is harnessed and harvested scientifically it can alleviate a lot of our health issues.

Miniaturization

Cutting edge research and emerging technologies have ensured that everything in this world is getting smaller and sleeker. Our built environment on the other hand is getting bigger, grander and completely out of control. The idiom of architecture needs a complete change in its vocabulary.

Chronopharmacology

The variation in solar radiation has different effects at different points of the day. Activities based on this understanding could help humans to be more productive and healthy. This could also lead to more effective medication. Our medical interventions could be more about healing than treatment.

Synchronizing the variables

Climate, weather, sun path, circadian movements and desired activities could be layered using a GIS (Global Information System) platform. This could be further fine-tuned using a GPS (Global Positioning System). An architectural expression based on this template would be sustainable and human centric.

II. CONCLUSION

Natural light in the form of solar radiation plays a very important role in human circadian rhythms. Spaces designed to align with the human circadian rhythms would ensure good health, happiness and result in better productivity. Solar

flushing would ensure better hygiene and reduced healthcare. This approach would go a long way in ensuring a better quality of life. It is completely passive, does not require any energy and has no negative impact on the environment.

The way forward

Humans need to connect with the sun and the sky—they have to go back to nature. A paradigm shift is needed in our approach to architectural design. Our design interventions need to focus on seamlessly merging our internal and external spaces. The architectural manifestations need to evolve based on human circadian rhythms, chronobiology, climate and activities. We need to build less and build only when absolutely necessary. Our built environment needs to factor in circadian rhythms, chronobiology, climate and desired activities in consonance with solar radiation and evolve an appropriate solution. This approach will ensure that all our architectural expressions are passive, sustainable, eco-friendly and have the least impact on the environment. If humans don't change the way they build and live the sixth extinction will be an anthropological one. Unless we change this appears to be only a formality.

REFERENCES.

Books.

- [1]. Francis D.K.Ching, Architecture –Form, Space and Order, 2nd edition, Van Nostrand Reinhold.
- [2]. Francis D.K.Ching, A visual dictionary of Architecture, 2nd edition, Van Nostrand Reinhold.
- [3]. PriyaChoudhary, Human approach to Urban Planning. Copal Publishing.
- [4]. Javier Senosiain, Bio-Architecture, Routledge-Taylor and Francis Group.
- [5]. Pete Melby and Tom Cathcart, Regenerative Design Techniques-Wiley.
- [6]. Rachael Carson, "The silent spring."
- [7]. Frederick R.Adler and Colby J.Tanner, Urban Ecosystems.Cambridge University.
- [8]. Roger Greeno and Derek Osbourn, Mitchell's introduction to buildings. Routledge-Taylor and Francis Group.
- [9]. Amos Rappaport, House,Form and Shelter

Journal article.

- [10]. Indraneel Roy Choudhuri and Dr.SuchandraBardhan, Evaluating water footprints of Building construction in India, ABACUS, volume-9, number-2.
- [11]. Rakesh K.S. and Dr. Abdul Razak Mohamed, Qualitative Analysis of Pedestrian Environment-A case study of Sardar Patel

- Road, Chennai. ,SPACE volume.13, no.2,2008.p98.
- [12]. Dr.Mahavir,Amartya Deb and Rajeev R.,10 Myths on Sustainable Development through an inclusive approach, SPACE volume.18, no.2,2014.p72
- [13]. Dr.P.S.N.Rao, Affordable Housing for Low income groups in Urban India-A prognosis

of policy and practice. SPACE volume.13, no.2,2008.p82.

Conference proceedings.

- [14]. PelinDursun, “Space Syntax in Architectural Design”.

Manohar Balasubramaniam, et.al. “A sustainable design approach for the built environment based on the principles of Anthropological circadian rhythms, Chronobiology and Chronopharmacology” *International Journal of Engineering Research and Applications (IJERA)*, vol.10 (02), 2020, pp 27-31.