Human Factors for Apparel and Textile Engineering, Vol. 32, 2022, 199–205
https://doi.org/10.54941/ahfe1001556

Thermal Comfort of Buildings and Their Occupants. Dialogue between Nature, Textiles and Architecture

Marlene Couceiro and Cristina Carvalho

CIAUD, Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, Universidade de Lisboa, Portugal

ABSTRACT

In this research we focus on cooling and heating techniques for animals, to try to find solutions, based on fauna and flora observation, to formulate possible textile and architectural applications. It is by no means intended to exhaust the subject; however, we will indicate some behavioral strategies and anatomical features, which help animals to regulate their body temperature. With this study we intend to understand the dynamics of Nature, to understand how it solves its problems, to understand its general process of efficiency, to observe its diversity and complexity, to take advantage of this inexhaustible source of inspiration for Design, Textiles and Architecture. It seems possible to improve the thermal comfort of buildings and their occupants through the production and application of responsive materials.

Keywords: Textiles, Innovation, Temperature, Smart-materials, Colour

INTRODUCTION

Our research has the general objective of combating thermal discomfort and improving the interaction between the user and the space, through the application of new materials. Textiles have been used in architecture since mankind began to build (Kronenburg, 2015). One of the advantages of their use is that they improve thermal comfort without increasing energy consumption. Like fabrics, animal skins are also used in shelters to control temperature. The strategy is to use them as heat shields or as insulating layers (Cook, 1996). Observing how animals withstand harsh conditions, imitating these behaviors, and even using their fur, in clothing or housing, makes it possible to combat the cold in winter (Usenyuk-Kravchuk et al., 2020). The natural coating of hides and feathers as insulation is widely used (Scholander et al., 1950). The skins of some animals, for example seals and reindeer, provide in many respects superior insulation to modern synthetic materials (Cotel et al., 2004).

The body envelope of animals, their fur, feathers and scales, functions in a similar way to the skin of humans. It has several functions (protection, communication, sensation, thermoregulation). Analysis of their protective and regulatory functions provides a starting point, for experiments in textiles and buildings. Some species of mammals (and birds) change their brown fur coats in summer to white in winter to facilitate camouflage in the snow, species that change coloration between seasons will have a better chance of adapting to changes in climate. For both predators and prey, being able to camouflage themselves in their surroundings is an advantage, as it increases the chances of survival. However, field studies show that due to climate change, the seasonal duration of snowfall is decreasing globally, which means that some species do not change their coat color in the winter, as would be expected. Animals are constantly adapting to rapidly changing environments (Jones et al., 2018; Afonso, 2018; Mills et al., 2018).

We can create a parallel with the sculpture Puppy, a work by Jeff Koons in the Guggenheim Museum in Bilbao, which has a changing cloak, whose "fur" grows irregularly. This sculpture of a West Highland terrier covered with plants has two outfits, a spring-summer and an autumn-winter version, the plants are changed twice a year and a combination of peat, metal mesh and geotextile fabric are used to support them (Martínez, 2017).

Edward T. Hall (Hall, 1986) explores the functions of the skin at the thermal level. Emotional states provoke changes in different areas of the body, as can be seen in animals, where the fur is used to regulate temperature. In birds, when a male is in the presence of another male, a series of messages are sent to the body to prepare it for combat. One of the changes suffered by the body is the rise in temperature, which triggers the thickening of the plumage.

José Melo-Ferreira, in turn, also points out, that this mechanism of changing the coat or plumage is used for cooling or warming the body, for example, if it is denser, there is greater protection against the cold (Afonso, 2018).

In humans, in adulthood, the growth of fine hair represents an attempt by the body to conserve heat. The appearance of lanugo hair, which grows on certain parts of the body such as the sides of the face, arms and back, can be associated with eating disorders. Patients with anorexia nervosa often have problems with thermoregulation and acrocyanosis of their hands and feet (Brown, 2000).

In this research the characteristics of animals are analyzed, to overcome the discomfort associated with the environment. Some current constructive solutions in our buildings involve, sometimes unconsciously, recreating the ways that humans and animals instinctively must overcome the adversities caused by the environment that surrounds them.

Let's think about birds, whose inflation system allows them to increase the amount of air trapped between their feathers when it is cold. We can create a parallel with today's construction. Let's look at a double brick wall of a house, which in the middle of the two brick rows has an air gap of varying thickness. Like birds, this air gap has a certain thermal transmission coefficient, which, together with that of the brick, increases the temperature transmission resistance. This makes it difficult for the warm air inside the dwelling to escape in winter, and in summer it prevents the warm air from the outside passing through to the inside. Exactly what happens with bird feathers. In cold weather they prevent body temperature from being easily lost. In summer, the opposite, they eliminate this layer of air to lose body heat more easily, keeping the feathers close to the body thus decreasing the insulating layer.

In humans, the shivers, are an attempt to create this insulation, a not very efficient strategy due to the lack of hair or hairs. Therefore, we add other layers, the clothing, that allow us to regulate our temperature (KhanAcademy, no date). This mechanism of birds “ruffling” their feathers may have served as inspiration for the development of smart textiles. For example, the partnership between the Self-Assembly Lab, MIT with the Ministry of Supply, Hills Inc., U. Maine and Iowa State U. has resulted in textiles that continuously adapt to the environment to keep us comfortable in ever-changing environments by reversibly changing to improve breathability, insulation or fit.

As with textiles, there are also kinetic facades, solutions with flexible, communicative, and intelligent qualities, with benefits in terms of information, efficiency, sustainability, and the environment. Dynamic structures, in motion, that adapt to light, temperature or rainfall automatically. What allows to create ideal shading conditions, to protect against heat and glare from the sun and decrease the need for air conditioning, or on the contrary try to capture more solar energy.

Enric Ruiz-Geli, founder of the architectural practice Cloud-9, designed the Media-ICT building in Barcelona (Kronenburg, 2015). The building has a double skin, which allows for increased or decreased shading. The panels contain a layer that inflates or deflates depending on the temperature. A dynamic architecture that allows the entrance of the sun’s rays, light, or heat to be avoided.

Another building whose facade functions as a reactive skin is Jean Nouvel’s Institute du Monde Arab in Paris. It is an example of adaptive architecture, in which its facades are reminiscent of mechanical “pupils”. This 1987 building consists of photosensitive shutter screens, which react to changing light conditions by opening or closing, like the human iris, to control the amount of light and heat entering the building through constriction and dilation (Mazzoleni, 2013). However, Axel Ritter points out the discomfort caused by this over-sensitive automation, which made it uncomfortable for users inside the building. This meant that a readjustment had to be made, so that there would not be a change at such short intervals (Ritter, 2002). As we saw earlier, in Nature it has been found that there is a close correlation between insulation and the thickness of the animals’ fur and skin (Scholander et al., 1950; Afonso, 2018).

However, in clothing this bulk can get in the way of freedom of movement. Clothing is used to provide warmth and protection, and there is responsive clothing that responds to temperature. Temperature sensors, when incorporated into a garment, can be used to detect both environmental conditions and body heat (Hartman, 2014). Smart textiles are currently available, which can confer benefits to their wearers by improving comfort and performance, for example by offering extra insulation in hot or cold situations. Let’s list some examples of smart clothing and wearable technology.

Grado Zero has developed a leather jacket with several functional layers, one of which is a moisture-wicking and heat-regulating climate membrane that controls perspiration permeability and heat flow in response to body temperature. Corpo Nove, through its spin-off R&D Grado Zero has manufactured a shirt with long sleeves, whose project name is "Oricalco". The sleeves can be programmed to shorten immediately as the ambient temperature changes (Ritter, 2002).

There are several changeable textiles on the market. Lauren Bowker, Rainbow Winters, Stone Island, Jürgen Mayer, Cry Wolf Child have presented pieces that function like a sixth skin. These brands/creatives have incorporated into garments and home textiles, ink that changes color in response to external factors (light, heat, water, and friction). Nikolas Bentel, Diffus, Nieuwe Heren, Sue Ngo and Nien Lan are some of the authors who have developed pieces, which react to environmental pollutants. Yvonne Chan Vili has developed Shape Memory indoor textiles, bringing together conventional yarns and temperature-sensitive SMA yarns, which change the width of their openings throughout the day (Ritter, 2002).

Thermal Comfort of Buildings and Their Occupants Dialogue Between Nature, Textiles and Architecture

This article examines the possibilities of integrating some animal characteristics, in textiles and coatings, to improve their thermal performance. In a previous study we concluded that several authors agree that the colors used in architecture influence the temperature of indoor environments. Therefore, the choice of color should aim to achieve better thermal performance of building structures. To avoid energy consumption used for heating or cooling the building (Carvalho et al., 2021). The use of darker shades, in textiles or buildings, allows more solar radiation to be absorbed and heats the human body or the walls of houses. While the use of lighter shades, contribute to a greater reflection of sunlight, which allows the surfaces to avoid heating up, favoring a reduction in temperature.

Color change in animals, besides serving for communication, protection/survival, and seduction/mating, is a thermoregulation mechanism. This color-changing characteristic that some reptiles have allows them to lighten or darken, thus affecting the amount of solar radiation they absorb. Crocodiles when young can change the color of their body slightly. Most snakes cannot change their color; however, rattlesnakes lighten and darken as they get warmer cooler. Lizards, clearly at an advantage can change the color of their skin and when dark heat up 10 to 75% faster than with light skin (Pough, M. Janis and Heiser, 2013).

A remarkable adaptation to an environment with limited resources is the Namibian desert beetle (Onymacris unguicularis), it has a surface area that allows it to harvest fresh water in the desert. Its strategy is, at night, to position itself at the top of the dunes, where the wind is greater. Being black, it can radiate heat to the sky, thus becoming cooler than its environment. When the moist breeze blows in from the sea, water droplets form on the beetle's back, which are channeled into its mouth, thus managing to counteract the desert heat. In addition to the beetle's posture, the hydrophobic coating of its shell makes this adaptation even more effective for harvesting the mist (Pawlyn, 2016). There are tents for refugees, where they try to use this technology, to get around the issue of water scarcity.

Like the texture of the beetle, the microscopic roughness of the surface of the lotus flower plant helps channel the water droplets present in the air, this repulsive effect of water, gives the surface cleanliness. In construction we can find materials with similar characteristics, in which self-cleaning properties are added, thus allowing the structure to remain clean for longer, thus dispensing with the consumption of energy resources. For example, the Jubilee Church, Rome, designed in 1996 by Richard Meier & Partners Architects, is characterized by self-cleaning concrete panels (Elvin, 2019). A material with similar characteristics, whose structure repels dirt is burel. The material from the cloaks of the shepherds of Serra da Estrela is a material used in Portugal in both summer and winter, both for clothing and housing. Due to its high robustness and resistance, burel has been exploited for clothing, decoration, and architecture. In nature nothing is lost, and everything is transformed. It is a material, natural and non-polluting, lent by the sheep. Shearing is a necessary act, for the comfort of the animal. This material is recyclable, renewable, and durable. Fabric made of 100% wool, whose characteristics bring some benefits in terms of acoustics, thermal and maintenance. One of the main advantages in its use is its resistance to intensive use (traction, tearing, pressure and light) without changing color and shape (Burelfactory, no date).

When we talk about comfort in our buildings, two vectors are undoubtedly present, thermal comfort and acoustic comfort. For aesthetic reasons, the interior of homes can be covered with fabric, tapestries, or carpeting. In the floors, besides improving the visual part, it also brings benefits in acoustic and thermal terms.

From a thermal point of view, a carpet conveys not only a sensation of visual comfort, but effectively a sensorial comfort, more practical, in that it does not cool or heat up as much as a rigid material, be it ceramic, stone or even wood. Ceramic or porcelain tiles are usually cooler surfaces, to get around this thermal discomfort they are often covered with rugs. Textiles provide a warming effect, but can also be applied as shading devices, for cooling the buildings. For example, exterior curtains, awnings, pergolas, and other textiles can create temporary shade during hot periods. Some of the functions of textiles in architecture are like those of trees because both act as filters that improve the thermal comfort of spaces and reduce energy consumption. Besides aesthetically improving the spaces around buildings, trees allow shading, shelter against the wind, regulate temperature, and reduce air pollution. This is an efficient passive method of solar control. Persistent-leaf plants mainly for warm climates and deciduous plants for all others. To take advantage of this effect they should be placed mostly near windows (Abdel Aziz, 2014).

CONCLUSION

We observed Nature and tried, to correlate it with existing examples in textiles and Architecture. The goal was to present strategies, which can contribute to find alternative solutions, which accompany changes, especially weat her changes. This research has contributed to pointing out new opportunities and solutions for designers to develop innovative surfaces using intelligent materials and new technologies. Understanding and consciously applying new materials can add benefits in terms of thermal comfort, sustainability, and interactivity. Exploring qualities such as sensitivity and adaptability of surfaces to the weather, our textiles, or our homes, can improve the performance of products and enhance the quality of life of their users.

ACKNOWLEDGMENT

This work is financed by national funds through FCT - Fundação para a Ciência e a Tecnologia, I.P., under the Strategic Project with the reference UIDB/04008/2020.

REFERENCES

Abdel Aziz, D. M. (2014) 'Effects of Tree Shading on Building's Energy Consumption', Journal of Architectural Engineering Technology, 03(04), pp. 131–140. doi: 10.4172/2168-9717.1000135.

Afonso, M. Â. (2018) ALTERAÇÕES CLIMÁTICAS — Para sobreviverem, há animais que terão de mudar a cor do casaco de peles, PÚBLICO. Available at: https://www.publico.pt/2018/03/03/ciencia/noticia/para-sobreviver-ha-animais-que-terao-de-mudar-a-cor-do-casaco-de-peles-1805166 (Accessed: 25 September 2020).

Brown, J. M. (2000) 'Medical complications occurring in adolescents with anorexia nervosa', Western Journal of Medicine, 172(3), pp. 189–193. doi: 10.1136/ewjm.172.3.189.

Burelfactory (no date) Versatilidade, Resistência, Cor e Textura. Uma História tecida através do Design., BUREL ARQUITETURA. Available at: https://www.burelfactory.com/pt/ (Accessed: 21 March 2021).

Carvalho, C. et al. (2021) 'Textiles in Architecture: Floors and Wall Coverings', in, pp. 632–637. doi: 10.1007/978-3-030-80829-7_78.

Cook, J. (1996) 'Architecture indigenous to extreme climates', Energy and Buildings, 23(3), pp. 277–291. doi: 10.1016/0378-7788(95)00953-1.

Cotel, A. et al. (2004) 'Effect of ancient Inuit fur parka ruffs on facial heat transfer', Climate Research, 26(6395), pp. 77–84. doi: 10.3354/cr026077.

Elvin, G. (2019) 'Building Green with Nanotechnology', in 2007 Cleantech Conference and Trade Show Cleantech 2007. CRC Press, pp. 167–170. doi: 10.1201/9780429187469-43.

Hall, E. T. (1986) A dimensão oculta. Lisboa: Relógio d'Água.

Hartman, K. (2014) Make: Wearable Electronics: Design, prototype, and wear your own interactive garments. Maker Media, Inc.

Jones, M. R. et al. (2018) 'Adaptive introgression underlies polymorphic seasonal camouflage in snowshoe hares', Science, 360(6395), pp. 1355–1358. doi: 10.1126/science.aar5273.

KhanAcademy (no date) Estratégias de controle de temperatura: Como o comportamento, a anatomia e a fisiologia ajudam os animais no controle da temperatura corporal. Available at: https://pt.khanacademy.org/science/biology/principles-of-physiology/metabolism-and-thermoregulation/a/animal-temperature-regulation-strategies (Accessed: 10 March 2021).

Kronenburg, R. (2015) 'Introduction: the development of fabric structures in architecture', in Fabric Structures in Architecture. Elsevier, pp. 1–21. doi: 10.1016/B978-1-78242-233-4. 00001–2.

Martínez, M. (2017) We will tell you everything about Puppy, the flower statue guarding the Bilbao Guggenheim Museum. Available at: https://blog.ferrovial.com/en/2017/10/flower-puppy-bilbao-guggenheim-museum/ (Accessed: 2 September 2020).

Mazzoleni, I. (2013) Architecture Follows Nature. CRC Press.

Mills, L. S. et al. (2018) 'Winter color polymorphisms identify global hot spots for evolutionary rescue from climate change', Science, 359(6379), pp. 1033–1036. doi: 10.1126/science.aan8097.

Pawlyn, M. (2016) 'Biomimicry in architecture'.

Pough, F. H., M. Janis, C. and Heiser, J. B. (2013) Vertebrate Life. 9th edn. Pearson.

Ritter, A. (2002) Smart Materials in Architecture, Interior Architecture and Design. Berlin: Birkhäuser Architecture.

Scholander, P. F. et al. (1950) 'Body Insulation of Some Arctic and Tropical Mammals and Birds', The Biological Bulletin, 99(2), pp. 225–236. doi: 10.2307/1538740.

Usenyuk-Kravchuk, S. et al. (2020) 'Arctic design: revisiting traditional fur clothing within the daily routine of reindeer nomads', Heliyon, 6(2), p. e03355. doi: 10.1016/j.heliyon.2020.e03355.