

Study of the Architectural Spatial Scale based on Ergonomics

Zhuo Qun Li^{1, a} and De Sheng Lyu^{2, b*}

¹Harbin Institute of Technology, 92 West Dazhi Street, Harbin 150001, China

²Harbin Institute of Technology, 92 West Dazhi Street, Harbin 150001, China

^aqunqun0805@sina.com, ^bdeshengl@hit.edu.cn

Keywords: Spatial scale, Ergonomics, Human-body scale, Privacy of space, Interpersonal behavior

Abstract. Research on the user's mentality and behavioral psychology has become an essential part of architectural space design. In this paper, spatial scale was briefly analyzed in the field of architectural design by classification. Study on ergonomics was mainly focused on the human-body scale, including human-body dimension, range of motion and human sensory scale. Through the study of architectural spatial scale and human-body scale, the relationship between them and their interaction with human spatial behavior was discussed. The privacy of space was analyzed primarily in terms of interaction between scale and behavior. By means of illustrating and comparing, the combined influence of architectural spatial scale and human-body scale on interpersonal behavior was analyzed on architectural space. In the field of space design, a study of the relationship between human and space was put forward, which explored methods to increase the rationality of architectural space design in order to promote people's spatial behavior and architectural service efficiency.

Introduction

During the long-term practice of production and life, designers had been paying more attention to the application of ergonomics in space design, so as to create an environment which could meet the needs of spatial behavior of human. Ergonomics is a branch of engineering science in which biological science is used to study the relation between people and their space environments, providing a theoretical foundation for designing space of rational function, comfort and optimal state of interaction between people and space. Through the study of ergonomics, we can make a better interactive relationship between users and building space, which can improve work efficiency and quality of life. What is more, Space can shape users' behavior and psychological states. On the other hand, space of more explicit and detailed classification is designed to meet a variety of users' behavior. Therefore, applications of anthropometric and psychological knowledge can help designers make their works better conform to people's needs, aesthetic requirements and spiritual expression.

Spatial Scale

Scale and Spatial Scale. Different from size which is constant absolute magnitude, scale is a kind of variable relative magnitude. It is not only a basic measure of spatial dimensions but also used to represent the feelings of people in space.[1] Architecture spatial scale involves the proportional relations of dimension between human body and structure, moreover, between structures. It can bring to people the senses of dimension which are subjective feelings based on objective dimensions. These senses are derived from that people in buildings take their bodies as rulers to measure the sizes of the structures. Therefore, the scales of structures are closely associated with the physiological and psychological scales of human bodies. From the perspective of architectural design, the research on the spatial scale is focused on the interaction of proportional relations and people's feelings.

Classification of the Architectural Spatial Scale. Architectural Spatial Scale does not only refer to the spatial scale of any construction unit, generalized architectural space is the space where people's activities proceed such as cities, square, park, residential area, landscape, structure, indoor furniture. Therefore, generalized architectural spatial scale refers to the proportional relations of dimension between human body and those spaces, such as the physiological and psychological senses

which the proportional relations give people, including urban scale, street-scale, building scale, neighbor scale, detail scale. Under the guidance of the people-oriented design concept, the designer needs to determine the scale of building space based on the space capabilities, therefore, with the knowledge of ergonomics, the study of relationship between architectural spatial scale and spatial privacy, as well as, the relationship between architectural spatial scale and communicative behavior, can better guide architectural design, improving users' comfort. [3]

Architectural spatial scale can be divided into four types according to the ratio of the space dimension and the human body scale, which are intimate scale, general scale, monumental scale and huge scale. (refer with: Fig. 1) For intimate scale, architectural space dimension matches the human body scale, which can accommodate a limited number of human beings, the distance between person and person, person and building space is intimate. For general scale, architectural space can accommodate more people, supporting the people's needs of activities. A certain space around each person will be generated. For memorial scale, building space dimension will exceed the basic needs of the human body scale, moreover, there is not only enough space to meet the physical needs of people, but also sufficient space to meet people's psychological needs. Memorial scale can give special spirit to the space. For huge scale, such as squares, architectural spatial dimension is far beyond human body scale. In this situation, the space can accommodate lots of people and events held in it

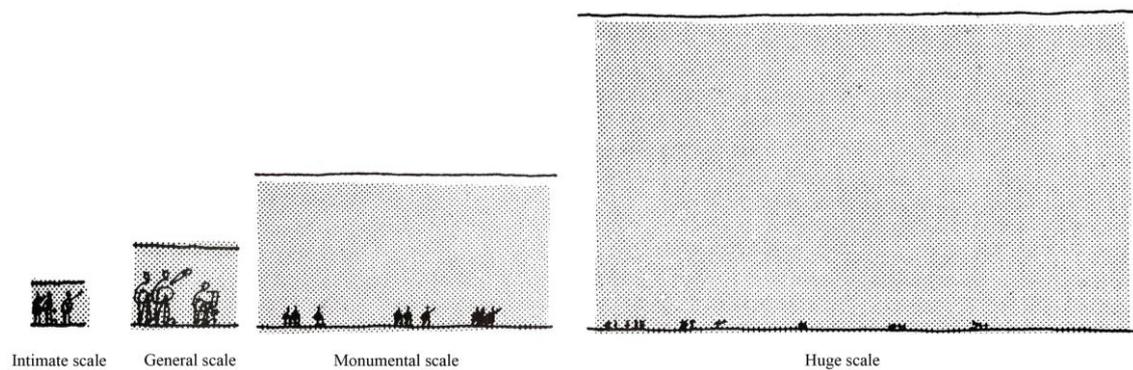


Fig. 1 Classification of the architectural spatial scale.

Human-body Scale

From the perspective of architectural design, ergonomics research is broadly focused on human body form data, human body motion parameters, characteristics of the human perception and response. [4] The function of ergonomic in space design is mainly reflected in the feasibility of building space design provided by the human body form data, and the basis of space environment behavior.

Human-body Dimension and Range of Motion. The human-body static dimension is the basic reference of space activity design. The basic data studied by ergonomics are the body structure sizes, including height, sitting height, shoulder, hip width, arm length, etc. [5] According to the survey of average height in China moderate body area, the height of adult man is 1700mm, and adult woman is 1610mm. Therefore, according to the body height, the minimum floor height in China is 2800mm. The dynamic range of body motion constitutes another factor of the space environment. Human action form is quite complex and ever-changing from sitting, standing, lying, squat, jump, spin, walk, etc. All these action forms will add to the requirements for multiple architectural spatial scales. Relative to human-body static dimensions, the application of fundamental space occupied by human activities is reflected in some dynamic scenes of life, such as sitting in a meeting, picking up something, working in the office, playing piano, taking clothes and kitchen operations. [6]

The age difference is an important factor affecting the dimensions of human-body. Architectural spatial scales should meet the human-body scale of different age groups, such as adults, the elderly

and children.[7] Depending on the body dimensions as well as the swing angle and lift height of leg are different. In the general architectural design, stair handrail height is 760 ~ 860mm, rise of staircase tread is 150 ~ 180mm, stair tread width is 220 ~ 300mm; In the design for children, stair handrail height is 600mm, rise of staircase tread is 120mm, stair tread width is 260mm; while in the design for the elder people, the rise of staircase tread 120mm and stair treads width is 380mm. By comparison, the elderly and children's body dimension and range of motion are smaller than the adults, so the architectural design must also have the appropriate adjustments, rise of staircase tread lowers and the tread width increases, which make the design more in line with the physiological characteristics of the users, bring more security and comfort.(refer with: Fig. 2)

Human Sensory Scale. Based on the distance of sense, the human sensory range can be classified into visual range, auditory range, olfactory range and tactile range. In this order, we see first, hear second, smell and come into contact at last. (refer with: Fig. 3). [8] Within the distance that a straight arm can reach is tactile range. Within the range of 1m, people can smell the weak odor from each other's clothes and hair. In the range of 2-3m, people can smell the perfume or other stronger odor. At a distance more than 3m, people can just smell very strong odor. In the range of 7m or less, people can have a general talk. In the range of 30m, one can clearly hear a speech. More than 35m away, people can only hear the shouting, and very difficult to understand the specific content. 80% of human rely on visual sense which has the widest range. The range of human vision varies with each individual. In the visual world, people refer to the contrast of surrounding environment and obtain a perception of scale. Within visual distance of 20-30m, people can clearly identify the architectural detail, within visual distance of 100-300m, the size and form change of doors and window can be identified. At a visual distance of 600m, people can only identify the shape and contours of the building. At 1200m visual distance, the single building transition to construction group, blank in the city streets and form a city silhouette.

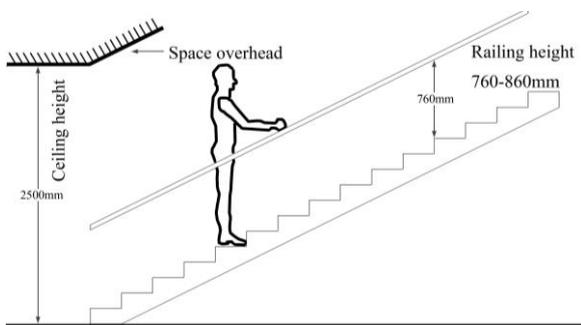


Fig. 2 Scales of stair.

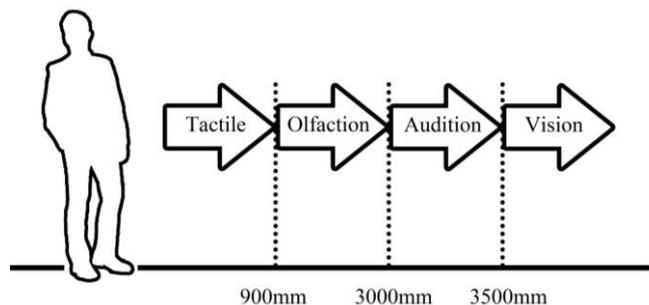


Fig. 3 Human sensory range.

Spatial Behavior

Privacy of Space. Space has the characteristics of public and privacy. It can not only get people together, but also separate us to different parts. Spatial privacy is an important feature of space, people need a sense of territoriality, and the pursuit of the sense of territoriality, is the main reflect of spatial privacy.[9]

We need to distinguish the private space from public space. We can divide the space into private space, semi-private space, semi-public space and public space by the level of privacy. Private space, such as living space is usually enclosed by truly solid walls with conservative design technique. The semi-private space is usually separated by some "soft partition" such as bushes or fences. The classification of space is based on the human sensory scale. Firstly, the privacy within human tactile scale is strongest, which is private space. Secondly, the space that can be reached by human olfactory and auditory scale is usually semi-private spaces and semi-public spaces. Thirdly, it will be public space that human visual scale can come into contact with. (refer with: Fig. 3)

Living space has the most frequent contact with us in our daily lives, making itself the best interpretative case of spatial privacy (refer with: Fig. 4). The villa garden is the semi-privacy space

around the villa. While the special scale is progressively decreasing, the privacy of space is increasing. The entrance and walkway are entire public space. Although there are two rows of low wooden fence on the both sides of the entrance to the street, but the impression it leaves us is still public for the feeling of territory is not strong enough. Through a trail corresponding to human-body scale, the semi-public space of the first-half yard, the semi-private space of the second-half yard and the private space inside the villa come to us in privacy order. This transformation indicates the ownership of the space silently and gives the user sense of belonging, safety and territory. In the transformation process, the designer makes a reasonable use of the human-body scale to create space of different privacy. In the semi-public space segment, wood fence and bushes are designed to limit people's behavior. In the semi-private space, there is wide-spreading lawn with a trail corresponding to human-body scale, pulling away people's sight of the villa. In the private space, plants taller than a person are designed to block people's sight. Through these clever ways, the privacy of the space becomes higher and higher, communicating the message of belonging, territory, control and remind people to act according with the privacy of the space. Privacy protection provided by the designer can be read from the spatial scale design.



Fig. 4 Privacy of living space.

Spatial Scale and Interpersonal Behavior. Space scale will limit and restrict people's spatial environment behavior. While we are designing our space, we can determine social distance and intensity between different people based on the different form communicative behavior in order to determine the scale and form of the space. We can make good use of spatial scale to influence and control the space between person and person or people and space. Therefore, the spatial scale can affect human behavior especially the communicative behavior. On the other hand, the human-body scale determines the spatial scale to some degree. For example, the width of the control gate is designed as certain values in order to limit the number of the people passing through at the same time. The average shoulder of Chinese adult is 375mm. If one can pass the gate with each hand carrying a bag, the width of the gate should no less than 550mm, 1100mm for two steams of people and 1650mm for three.[10]

According to the classification of human sensory scale and communicative behavior, the distance that communication require can be summarized into four kinds: intimate distance, personal distance, social distance, public distance. The distance is a spatial scale when compared with human-body scale. The challenge that space designers face is to let the distance promote the social behavior rather than inhibit it.(refer with: Fig. 5) Intimate distance is a range within 0.5m, which can be taken as a reference distance by intimate spatial scale. It is the distance for strong expression of comfort, anger, caress and other emotions. Communications within intimate distance usually happen in living space and other space of high level of privacy and has the highest intensity. Intimate distance is the minimum distance for strangers. Personal distance is a range of about 1.2m, which can be taken as a reference distance by general spatial scale. Communication at personal distance is usually between close friends or family members, and often happens in the living room and dining room. Social distance is a range of about 4m, which can be taken as a reference distance by general spatial scale. It is the appropriate distance for general friends and colleagues to communicate at a moderate volume.

Public distance is a range greater than 4m., which is appropriate distance for meetings, lectures, and other serious office activities.

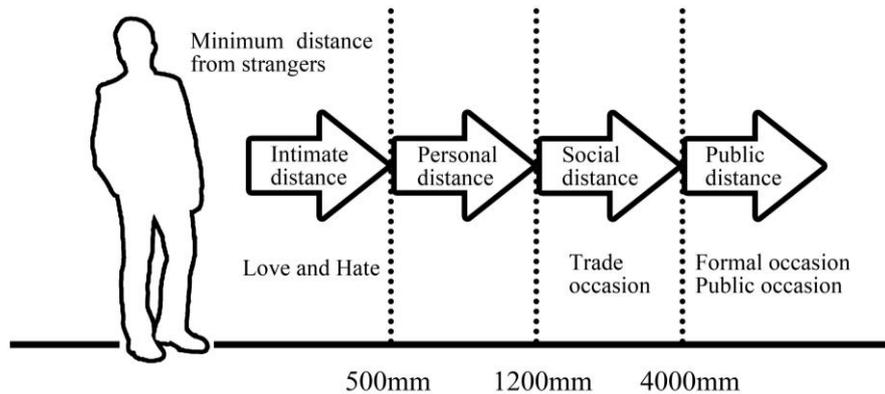


Fig. 5 Interpersonal distance.

The internal causes that affect interpersonal distance are physiological and psychological. Firstly, the divisions of interpersonal distance rely on human sensory scale. Tactile is a high-strength contact, so the range that tactile can perceive is classified as intimate distance and personal distance range. Olfaction is contact of relatively high-strength, so the range that people can smell can be classified as the social distance. Auditory and visual contact has lower intensity, so the range that people can hear and see is classified as public distance. Therefore, knowledge of human sensory scale can offer support to the design of architectural spatial scale that the desired interpersonal communication distance needs. Secondly, interpersonal distance is actually a macroscopically response to psychological distance, and the combined effect of similarities and differences of each individual's personality, feelings, thoughts, customs and other aspects. For example, differences in custom cultural background will largely affect interpersonal distance, different living patterns and distance awareness often give interpersonal distance different definitions. Social identity and status also affects interpersonal distance, generally, the distance and the status have positive correlation, meanwhile, the interpersonal distance of the upper classes of society tend to greater than that of the lower classes for the restrictions from the complicated social etiquette. This psychological distance is objective, not easily affected by the external environment. At the same time, it is also necessary because during the social interpersonal communication, people need to establish individual space for self-protection and form a psychological buffer zone to reduce friction with others and improve communication efficiency.

Interpersonal distance is also affected by some external causes. These causes mainly refer to the space constraints on people. Spatial population density will undoubtedly affect social interpersonal distance, the greater the density the smaller the distance. The positions of the people within the space will also affect the interpersonal distance, such as in the international negotiations among over the two countries, in order to create a "sense of equidistance", rather than leave anyone out, roundtable is usually used. The form of space also affects social interpersonal distance. For example, people separated only by a wall from their neighbors, although the spatial distance is short, but the partition wall blocks the communication and forms a long interpersonal distance.

Summary

At the perspective of architectural spatial scale measured by human-body scales, it will be easier to design the architectural spatial scale which the desired interpersonal communication distance needs. The meaning of space to the user is the space is able to be the necessary condition of the spatial behavior required by the user. Spatial behavior depends largely on the spatial scale and human-body scale. Ergonomic analysis can be used as an important tool for studying human-body scale and spatial scales as well as the interaction between them, and provides an important basis for the rational design

of architectural space. Spatial behavior is influenced by the architectural spatial privacy and spatial scale. Designers can distinguish the privacy of space and determine the architectural spatial scale according to the human sensory scales. In this way, spatial behavior can be promoted markedly and the service efficiency will be enhanced notably.

Acknowledgements:

This research is funded by Heilongjiang Provincial Natural Science Funds of China (Grant NO.:LC2013C19).

References

- [1] X.J. Zhang, S.X. Li: Architectural Criterion and People`s Psychology, Vol. 15 (1999) No.02, p.96-99.(In Chinese)
- [2] Y. Sun: Analysis of Several Views on the Spatial Scale of Existing Buildings, (2011) No.06, p.193+251.(In Chinese)
- [3] Y.Y. Shi: Building Space Design Based on Environmental Psychology, (2014) No.05, p.56-57.(In Chinese)
- [4] Q. Li, Y. Xiao: Application of Modern Ergonomic Design, (2010) No.28, p.236.(In Chinese)
- [5] X. Wang, X.W. Yang and W.B. Yang: *Human Engineering Introduction to Human Body Engineering Application in Modern Design* (Yong Publishing Group, China 2013).
- [6] Y.M. Zhang: *Environmental Behavior and Ergonomics* (China Electric Power Press, China 2011).
- [7] J.X. Li: *Proportion and Scale of Architecture* (MS., Southeast University, China 2004), p.60.
- [8] Bryan Lawson: *The language of space* (China Architecture & Building Press, U.K. 2003).
- [9] Y.C. Zhou: *Scale Study of the Morphology of the Indoor Space* (MS., Hunan Normal University, China 2013), p.24-26.
- [10] Q. Sun: *The Application of the Human Body Engineering in Building Channel Design* (MS., Qingdao University of Science and Technology, China 2014) , p.7.