A BODY-SURROUNDING STUDY IN PHYSICAL, VIRTUAL AND MENTAL SPACES

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Abstract. With the flourishing of architectural creation via all kinds of media, a comparison among physical, virtual and mental space becomes a fevered issue about spatiality due to the similar sense of space. This study reveals that even if the spaces constructed with distinct essence, a body-surrounding relation is an efficient way to formalize the problems of spatiality and relativity among three typical spaces. The sense of space and relative position reasoning were depicted with the Space-Transforming Test and the Space-Comprehending Test as a new concept about spatiality in general.

1. Introduction

The concept of “spatiality” has always been one of the most fundamental issues throughout the process of architectural design. Design problems from “how to structure a pertinent space?” or “What kind of spatial quality provides the sense of assimilability?” to “what exactly is spatiality?” can often be asked as the core objective in any form of architectural design, which is to create pliable spaces for humans. Consequently, during the evolution of design theory, the perception of space is ceaselessly cited and justified by concepts of abstraction and the perceptible body. These perspectives comprised the notion of subject versus object, and borrowed from 20th Century analytical methodology in psychology to develop social psychology or behavior studies. Hence, the spatial concept in the understanding of architecture is not only the depiction of a body-surrounding relationship fashioned by architectural elements, it is also used to engross human behaviors and time qualities, as well as to manage how the two fundamentals interact to create intimate relationships with the ambiance. This
is the reason during the recent years that much cognitive psychological research has generated deeper spatiality theories and exploration in interacting processes of user behavior in opposition to space.

However, the scope of architectural design and its comparative issues of discussions are not merely the fine-finished edifices of actuality. During the history of design development, various forms of materials, medium, visualization techniques and concepts have attentively been applied to carry out our design simulation experiences. Yet only after the advancement of design techniques and tools, design medium have broadened from merely imaginations and concepts into visual image representations, 3-dimensional models and perspective representations. In recent years, digital instruments have rapidly integrated design medium, and spatial simulations are no longer restricted to the traditional applications with the enhancements of 3-dimensional and multi-media animations. Although such types of concept representations can cause powerful impacts on our senses, they will also provide us with a concrete experience of spatiality as well as empowering the innate capabilities of spatial impacts and remembrance.

With the flourishing of entertainment businesses, and the accessible information flow of the Internet era, these animated simulations have been strongly deployed into special effects and animations for show biz. For example, “virtual spaces” such as online games and chat rooms have become a fevered issue in the field of architectural design, where the comparatives among physical, virtual and mental spaces substantially become apparent.

The initiatives of this research concentrate on the challenge of integration of architectural theory and cognitive science, and its relational impacts to human beings and surroundings in comparison within the context of spatiality to create types of distinctive diversities or contrarily analogous stimulations under variable spatial structures.

1.1. SPATIALITY IN ARCHITECTURAL THEORY

1.1.1. The development of spatial theory
Spatiality is derived from the enclosure of architectural elements, participation of people in it, and timing transitions. It is always an important issue in architecture (Bloomer and Moor, 1993; Giedion, 1967, Zevi and Barry, 1993). Besides the objective world of material, and the subjective world of consciousness, authentic and co-existing of both worlds are apparent (Benedikt, 1991). Therefore projecting the external world forms a synthesis of perceptions and experiences. Those mental images are opposite to the external world and are called mental spaces. From the viewpoint of architecture, Bloomer and Moore (1993) used internal landmarks as a way to describe people’s internal spatial perception. Also, architectural spaces and
forms have even been continuously evolved due to the appearance of new concepts of space in mind (Liu, 2001).

Before the idea is concreted by actual building it, there always needs to be a certain media to represent the idea for studying and communication in design process. The invention of the perspective drawing allowed people to describe a space which did not necessarily exist (Bloomer and Moore, 1993; Giedion, 1967; Zevi and Barry, 1993). These outcomes of designing activity with media sometimes are seen as a kind of space built in an anti-physical world by designers (Zevi and Barry, 1993). Now there are lots of three dimensional (3D) simulations represented with multimedia applications and getting out of physical limitation. Those are not only the copy of 3D space in physical, but a kind of multi-dimensional appearance (Palumbo, 2001). Via the monitor and internet, abstract architectural concepts can be combined with different information; related images can be interpreted and are called “liquid architecture” (Novak, 1991). Not only does it influence behavior and the design process, it also represents a challenge to existing spatial concepts (Mitchell, 1995, 1999; Liu, 2001).

1.1.2. The body and surrounding relation in architectural theory
Virtruvius tried to find out a basic module for an ideal building by depicting the proportions of the human body. The relation between the body and surroundings came out of architectural rules dealing with temple building. From then and on till the Renaissance, designers began thinking highly of how a person see his external world through vision exactly. With the rules of perspective used in drawing, the body was considered as a kind of measuring system. This was figuring the world out with a mathematical method. However, the way to one perceives the external world is not only through visual function but also hearing, touch and others are important.

The Cartesian’s dualism had been recommend for exploring both thinking unit and body unit in architectural theoretical development. The autonomy of a body is identified as “Logic of the Sense”, which is mechanical and organized sensory system of perception. Consequently, the form of a building should be accommodated to sensory rules rather than only the proportion of body (Palumbo, 2001). There are more and more artistic creation and edifice exhibited on all kinds of multimedia and stimulating viewers personally on the scene with visual and acoustic effects. Novaka (1998) indicated that the body is the intermedium between the three dimensional real space and multi-dimensional imaginary space.
1.2. SPATIALITY IN COGNITIVE RESEARCH

1.2.1. Sense of Space
From cognitive viewpoint, it’s necessary to reveal the behavior such as spatial comprehension, sensation and reasoning to understand how to deal with solving spatial problem. The first step was to investigate those perceptional factors like vision, hearing, touch, equilibrium and gravity (Epstein and Rogers, 1995). However, most spatial experience comes from dynamic stimuli during navigation and observation instead of static condition (Lynch, 1960; Tversky and Lee, 1999). The information comes from perception through viewer’s engaging in certain space and must be coded as classified spatial data for thinking and reasoning (Newcombe and Huttenlocher, 2000), such as an object-oriented way to depict external world (Saariluoma and Maarttola, 2001). There is an explicit distinction between physical and mental space. The first one makes body perceive space via visual image, characters and icons, while the other one, the projection of external world, is a systematized place abide by the regulations of importance and relativity (Tversky, 2001).

1.2.2. Perceiving body-surrounding relation
Human orientation and spatial cognition partly depend on the ability of memory sets of visual landmarks and imagine their relationships with people from different viewpoints (Oman et al., 2000). Therefore how does mind construct ideas and manipulate spatial information is a good approach to analyze what external world we can perceive. It includes the space of the body, the space around body, the space of navigation and the space of graphics (Tversky, 2001). In these researches, the applications of reference frame, an important rule to solve spatial problems, have been proved with Mental Rotations Test, the Map-Reading Test and the Perspective-Taking Test. Those are so-called spatial ability of mental transformation, which is including object-based transformation and egocentric perspective transformation via parametric information (Zacks et al., 2000; Logan and Sodler, 1996). Besides the former studies, Mental Animation, Visual-spatial working memory and Verbal working memory are all significant issues (Sims and Hegarty, 1977).

1.3. COGNITIVE RESEARCHES IN ARCHITECTURAL SPACES
With the beginning of cognitive way in researches of solving design problems, Lynch (1960) recommended that there are certain rules of ideal architectural space on the basis of people’s well comprehension. Nowadays, many architectural researches, cyberspace and spatial organization of digital city et
al, make use of this cognitive way to seek a better way clarifying how they look like. Most researches related to this method are influenced by spatiality of cognitive map of Lynch. For instance, Strohecker (1999) used this idea as criteria of navigation and perception in virtual spaces. Therefore both physical and virtual spaces are external creation for communicational usage (Tversky, 2001). People can feel “live in side” in a physical space, but lack infinite spatial experience like in virtual and mental spaces (Liu, 2002).

According to Kwan (1999), people usually has similar behavior both in physical and virtual spaces. On the other hand, other researches tend to focus on the analysis of spatiality formed by various spatial qualities and structures by deploying the elements of motion, interaction, and sounds as dominant factors in spatial representations. When talking about the virtual space in cyberspace, imaging is the major part for verbal creating sense of space. On the other hand, visual images recall the spatial feeling of viewers by mapping (Liu, 2001; Wong et al, 2001).

2. Body and surrounding issue in space

Due to the impacts on physical space, time and regional relationship brought by concepts of virtual spatiality formed by digital design tools, the architectural research progression in co-constructed relationship of physical, virtual and mental spaces thus applied the contrast of physical spatiality versus imaginations as specimen at an earlier stage in order to develop digital representations. Nowadays, the digitalization can effectively create virtual images authentic as reality, which is why many scholars have brought up the coexisting of manifold spaces concept. Mitchell (1995, 1999) used binary opposition, material, virtuality and new categories of city to show how physical space and virtual space can coexist with one another. Liu (2002) approached the issue from the point of view of imaginative tension, suggesting that media make virtual space a kind of compromise between physical space and mental space. Therefore besides mental space and physical space, there is also a virtual space, and his description just explains that virtual space has the characteristics of infinite imagination and the physical sensation between mental space and physical space.

However, spatial characters are not totally absolute in different spaces. For example, because of valid social activities, a performance scene with temporary spatial quality in physical world even gives out much more fictitious and virtual sense than a 3D website or Chat room. As the actual efficacy resulted from the lengths of its existing period and occurrences, the degree of virtuality of the texture and structural method of the space is thus diversified. Since there are lots of activities and behaviors valid in a virtual environment, how could we ignore the existence and significance of virtual space? Furthermore, all the concepts mentioned above are used in the form
of contrast to describe the different experiences created by physical, virtual and mental spaces, whilst the ambiguous spatial qualities still remain.

In order to formulate the emerging issue of the comparison among three main spatial ideas, physical, virtual and mental spaces, we should avoid distinguish one from another with analogically way. The previous researches also reveal an important issue that the interdependence of body and his surroundings in both architecture and cognitive science. Hence, the analysis of such spatial quality should not be observed by its composition submissively, but also has to be observed from how human interact and response to spaces under the stimulations of different surroundings. How does the interdependence between body and surroundings to form the perception such as “sense of space”? Will the relationship and nature of body and surrounding change when transforming from one type of space to another? This study sought clarification of spatiality from those viewpoints, so it can explain why all these spaces give us similar feeling of spatiality although there are disparities in spatial cognition.

3. Methodology

3.1. SETTING EXPERIMENTAL CONDITION

3.1.1. Participants
Although virtual space is applied as a communication tool for simulation and discussing in design process, perceiving similar sense of space is no matter who he is. In order to avoid subjects having particular visual training or experience, subjects were included six architecture-background students and another six students without architectural training.

3.1.2. Environmental material and experimental equipment
A physical space is a real building or room familiar to us. There were two architectural cases chosen in this study, one is Taipei Fine Art Museum the other is a rectangular room. A virtual space can appear with several types. In this study the virtual spaces were showed both simulation of a real building and an anti-physical building. In order to make subjects free to choose the path and perspective they want, VR cave equipment was used as an interface of digital information (Figure 1). The subjects could navigate the virtual spaces via sensors as feedback of visual and acoustic stimulus. The construction of mental space is separated into two parts: active imagination of representation and passive memory of map-reading.
3.2. PROCEDURE

3.2.1. Warm-up experience for instructions
First part is a definition test of three dimensional environments and its purpose is to affirm spatial understanding and capability of subjects. By using computer tests and three dimensional models, subjects will understand real, visual and mind spaces defined by author. Another part is about ability of execution in virtual and mental spaces. The motion sensors (including infrared device) were used to make subjects familiar with navigation in VR cave environment. A short path was assigned to help subjects to read instruction maps and explain this path via any draft and diagrammatic note. Besides we encourage subjects to describe the feeling, think and motion throughout whole experiment while the protocol data are collected with DV record beneficial for our collection and analysis.

3.2.2. Experiment 1: Spaces-Transforming Test
In the first experiment, the environmental materials were real building case and non-real building cases (Figure 2). Taipei Fine Art Museum, a public place for exhibition, was chosen as a real building case for subjects to navigate in experiment. There was a simulation of this building used to be a kind of virtual space. Non-real building case in this experiment meant it could not be built in real space or its physical properties did not exist in real space. Some graphs and icons were regarded as textures of three dimensional objects. These objects were created to stimulate similar experience of visual navigation compared with our experience in real world. RV cave was used as a representing tool to increase the reaction between viewers and visual space and to decrease the effect of interface flatness and visual limit. Then utilizing the memory after experiencing and representing of spatial logic was useful to understand how it reacts in mental space.

At beginning of these three different environments, physical space and two types of virtual space, the subjects were given map and textural information

Figure 1. VR cave (the virtual space interface)
as instructions to navigate the spaces, then subjects had to describe the space after navigating another part of the spaces. At the same time DV was utilized to record processes as protocol data with thinking-aloud method. In this way, it could reveal how external spatial information forms internal comprehension via perception and how internal spatial reasoning reacts to external space.

Figure 2. The three experimental environments. (From left to right, Taipei Fine Art Museum in physical, virtual space and non-real building in virtual space)

3.2.3. Experiment 2: Space-Comprehending Test
In the second experiment, the environment was a rectangular real space and eight different things were put in four corners specifically. At the same time, a same virtual space was built with 3D modeling software. Than display this simulation on a screen of PC, VR cave with one surface and VR cave with three surfaces. First, the subjects were given some 2D diagram to remember and figure eight objects out. When a subject got into the space in an unexpected perspective, he was asked to describe what else object out of the field of vision. After rearranging, subject was asked to remember the positions of objects in one minute and then to describe what else in an unexpected perspective too. Those subjects could ask for pencil and papers to take notes or help reasoning. All the process and notes would be recorded with DV.

4. Results and Discussions

4.1. EXTERNAL SPATIAL INFORMATION AND INTERNAL COMPREHENSION
Most of the participants felt that stimulation on the sight and hearing organs as well as whether or not one is able to control their direction, speed, and self-recognition in the specified space are all important sources of spatial sensation. Furthermore, moving objects in the surroundings or interaction, communication or even changes in the space status, etc. In addition to the
response toward external space stimulations are also significant factors for whether or not one could feel “being within it”. Therefore spatiality is not only arrangement of 3D objects, but unceasing transformation between external and internal spaces with perception and reaction (Figure 3).

**Figure 3. The relativity between external spatial information and internal comprehension**

4.2. TO CONSTITUTE A SPACE

Therefore, spatial sensations in both physical and virtual spaces are formed in similar way. Aside from the three-dimensional space that objects take up, it must give the body sufficient stimulation on the organs and provide the possibility for certain types of behavior. Virtual space is created through the documentation and presentation by the media, simulating real space to give the body stimulation. For example, VR cave’s three-dimensional effect and binocular perception allows different organs of a body to accept different messages. Another example is the surrounding stereo effect, used to present an object’s three-dimensional feeling and hearing in virtual space. Meanwhile, the sense of touch and smell are less used as building factors in virtual space. On the other hand, if virtual space is not limited to the technical problems of presentation, then the object’s dimensions can be enlarged or shrunken at will, while the possibility and freedom of behaviors will be greatly expanded because they are no longer bounded by their physical features and structure. But there still some limitation in these experiences. Such as representation of virtual space depends on technology of manipulating and equipment and the mental space may be influenced by specific learning experience or oral ability.

4.3. COMPARISON

In the second experiment, only visual stimulation was used as the factors in survey for space sensation and was applied to physical space as well as different sized interfaces and presentation forms within virtual space. The
larger the scope of the virtual space’s interface and the ability to provide binocular visual stimulation of 3-D presentation, the closer it becomes to the optical experience in real space. The reasoning ability of space and reacting time are about the same in either physical or virtual space. As for the part on using two-dimensional pictures as a source of recognition learning, the participants were inclined to first mentally transform the 2D picture into a first person’s visual imagination, and then compare the image seen by the eyes before making further judgment on the object’s location. As for the pre-navigation experiment part, the participants tended to first remember the image seen by the eyes and the relationship of each object with themselves. Then when making their judgment, they will compare the image in front of their eyes with their earlier memory and then judge the relative relationship of the memorized objects.

With regard to comprehension ability, either architecture-background subjects or others reactive time and correct rate are about the same in physical space. Because the limitation of facilities and manipulating uneasily, both two kinds of subjects felt virtual space in VR cave that were harder to be recognized. It was found that most architecture-background subjects were better at comprehension of spatial organization and dealing with the reasoning in virtual environment for their familiarity with simplified spatial information. Besides reaction to different spaces, the protocol data shows that architecture-background subjects paid more attention on describing features of external objects. And they were trying to compare characters of different things more often. While others used sentences such as “I feel…” and describing compounded feeling frequently. But basically both depiction of surroundings and self behavior or reaction were be maintained. In the second experiment, after entirely understanding the state, the averages of correct rate of subjects are almost the same regarding subjects of two categories. Therefore spatial reasoning seems a basic ability for people to understanding, thinking, and representing a spatial problem. But the subjects without architectural training consider more texture looks like a “real objects” more they think that is an existent space, while more architecture-background subjects focus on well organized objects in three dimensional environments.

5. Conclusion

5.1. SENCE OF SPACE

The formation of space comes from the location and distance of different objects in proportion to the body. Through the interactive relationship came from by the body’s senses and behavior, a “being within it” feeling is formed. Therefore, spatial sensation is the conversion process between the body’s
external messages of space and internal mental space, i.e. only through the
detection of stimulations by the sense organs of perception and reaction
formed by one’s behavior can external space features be completely
described. Hence, the behavior model for generating spatial sensation of
physical and virtual space is the same. However, the difference is, virtual
space’s stimulation source toward the body utilizes the same digital signals to
create images or sound frequencies, simulating the visual and other feeling in
real space.

The creation method of internal space is greatly different from external
space. The surrounding objects in one’s mental imagination come from
recorded experiences regarding external space as well as imaginary results
of creation. Therefore, like virtual space, which is not affected by the
physical characteristics of the material and surroundings, space series
arrangement in mental space is also very free. Moreover, no matter whether
the surrounding object is in physical space or virtual space, it is the source of
spatial information for everyone as shared experience, yet the mental space
created through different component and reasoning makes it into
individualized spatial information.

5.2. THE BODY-SURROUNDING RELATION

Revealing the state of relation between body and surrounding is a
fundamental way to understand spatiality (Table 1). When a body perceives
or recognizes some spatial information from what surround him, coding these
stimuli is the basis step to classify the thinking elements. Such as coding with
object-oriented method, therefore each object can be described with its
identity, direction and distance from viewer. Science we can change the
relative position by motion or action, we usually have to deal with spatial
reasoning ability in our mind, the mental space, before making a decision.
Therefore using reference frame such as object-based spatial
transformations and egocentric perspective transformations is the basic rules
of spatial reasoning. The issue of interactive degree comes from can body
and surrounding objects move, alter and be interdependent. This capability of
reacting to one’s surrounding is the other part of spatiality.
TABLE 1. The characters of body and surroundings in physical, virtual and mental space.

<table>
<thead>
<tr>
<th></th>
<th>PHYSICAL</th>
<th>VIRTUAL</th>
<th>MENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body</strong></td>
<td>Nature</td>
<td>real body</td>
<td>real body or virtual avatar</td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td>stable</td>
<td>stable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>uneasy to change</td>
<td>easy to change</td>
</tr>
<tr>
<td><strong>Surroundings</strong></td>
<td>Nature</td>
<td>real material</td>
<td>digital data</td>
</tr>
<tr>
<td></td>
<td>Sequence of spaces</td>
<td>stable</td>
<td>stable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not easy to change</td>
<td>easy to change</td>
</tr>
<tr>
<td><strong>Relation</strong></td>
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<td>vision</td>
<td>vision</td>
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<td></td>
<td></td>
<td>hearing</td>
<td>hearing</td>
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<tr>
<td></td>
<td></td>
<td>smell</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reaction</td>
<td>navigation</td>
<td>navigation</td>
</tr>
</tbody>
</table>

5.3. THE NEW CONCEPT ABOUT SPATIALITY

Most architectural theory comes from experience of physical world through the ages. In fact, a memorial and valued building should be able to touch people deeply in the heart. That is a body can perceive the space and interacts with his surrounding. However, note only a material-based building can be sensed as space, but also organized mental imaginary and fake world in animation do.

Therefore this study sought for exploring the context and relation among the three kinds of spatial perception with a serious experiences and analysis about body and surroundings in each considered spatial type. No matter how a space is constructed, a body-surrounding relationship is the same framework for surveying the appearance of specific space (Figure 4). The transformation between different spaces is varying the nature of body and surrounding object (Table. 2). For instance, with digital image and acoustic effects, a virtual space can simulate those perceptions in physical world. While we want to concretize the creative idea in our mind, only creating external material construction or organized data by us, spatial concept in mind can be shared for communication. Therefore both body and surroundings are fundamental of a meaningful space, and they all co-exit in physical, virtual and mental spaces. At the same time, it revealed that to construct a sensible space not depends on real material but abundant spatial information from all aspects. Future research will examine the presentation of digital media and how they provide more direct spatial perception. In this way, our spatial experience can be enriched with multi-space and some traditional architectural theories and concepts will be reformed.
Figure 4. The Conceptual Relationship of three kinds of spatiality

TABLE 2. Transformation between different spaces via varying the nature of body and surroundings

<table>
<thead>
<tr>
<th>NATURE</th>
<th>CHANGEABILITY</th>
<th>SOCIALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Body</td>
<td>Surroundings</td>
</tr>
<tr>
<td>Mental</td>
<td>Imagination</td>
<td>Real</td>
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<tr>
<td>Physical</td>
<td>Real material</td>
<td>Physical rules</td>
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<td>Mental</td>
<td>Imagination</td>
<td>Digital data</td>
</tr>
<tr>
<td>Virtual</td>
<td>Real</td>
<td>Parameter rules</td>
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<tr>
<td>Physical</td>
<td>Real material</td>
<td>Physical rules</td>
</tr>
<tr>
<td>Virtual</td>
<td>Digital data</td>
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References


