THE CORRELATION BETWEEN AUDITORY COMFORT AND SPATIAL SCALE OF “TV WATCHING” BEHAVIOR OF ELDERLY PEOPLE

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Abstract: Background: Auditory sense is an important guarantee for the elderly to communicate with the outside world. Hearing comfort is of great significance to the construction of mental health and the improvement to life quality of the elderly. However, researchers have paid less attention to studies on the auditory comfort of the elderly in space design. Objective: This study was conducted to investigate the correlation between auditory comfort and spatial scale in "TV watching" behavior of elderly people. Methods: By recording the daytime behavior of 60 elderly people in a nursing home in Tieling city, it was determined that the main auditory behavior other than conversation was "watching TV" behavior. This experiment first graded the hearing level of the elderly, and then collected the evaluation of the auditory comfort of "watching TV" behavior on different spatial scales by means of subjective evaluation and scoring Level 5. Data were analyzed in SPSS using Pearson correlation coefficients analysis. In the end, using the Ergo-LAB, the technical platform recorded the elderly physiological signals (skin electrical signals and pulse signals). Combining the qualitative analysis of subjective evaluation, ErgoLAB software was used to analyse the relationship between physiological signal and spatial scale quantitatively. Results: There was a strong negative correlation between auditory comfort and spatial scale in "TV watching" behavior in the hearing impaired elderly (P<0.001). And there was no significant correlation between the two in the hearing normal elderly (P=0.285). At 1.6m and 3.1m, the change value of skin electrical signals of hearing impaired elderly people was the largest, and the TP value was lower. Conclusions: Different hearing levels correspond to different auditory comfort space scales. For the elderly with normal hearing, the auditory comfort distance during TV watching is 3.1m and 1.6m. For the elderly with hearing impairment, the distance is 1.6m.

Keywords: mental health, auditory comfort, space scale, correlation, elderly people

1. Introduction

Studies suggest that perceived comfort is an important factor affecting people's mental health. More and more examples show that people's health needs to consider both physical health and mental health in modern life [1]. Mental health is often one of the aspects that people tend to ignore, or the factors that affect it are often the result of people's passive choices. Factors affecting mental health include work and social pressure as well as the perception of people's living environment [2]. The comfort of the environment depends on the considerations at the design stage. Users are not able to predict the impact of their environment on their mental health in advance, and this effect is gradually generated through contact with the environment. And some uncomfortable and unreasonable environment brought about by the
psychological effects of the bad often after know. Therefore, designers should have a more comprehensive and humane consideration of the design at the beginning of the design to avoid these situations.

At present, China's population aging problem is becoming more and more serious, and other countries in the world also have aging population problems to varying degrees. The elderly have become the service object that academic circles cannot ignore. With the growth of age, the old people's various bodily functions gradually decline, among which the visual and auditory effects are the most obvious. Eighty percent of Americans over the age of 65 have at least one chronic disease, the most common of which is hearing loss [3]. Although hearing impairment has a small impact on the length of life, it has a large negative impact on the quality of life, cognitive ability, emotion, social behavior and communication ability. According to the survey results, there are great individual differences in the response of the elderly to deafness. Some elderly people can fully accept the fact of deafness and make positive personal adjustments. Others see themselves as cut off from the outside world, with a sense of loss that reduces social interaction [4]. Elderly people have limited access to information, and their hearing loss further limits their ability to obtain information, which has a huge impact on their communication and aggravates their anxiety, loneliness and loss. Over time, it will increase their psychological burden and even cause serious mental illness.

Meanwhile, as the most direct embodiment of the living environment of the elderly, architectural space for the aged has become a worldwide research content. Since 1999, China has issued relevant standards such as the code for the design of buildings for the elderly, the code for the design of residential buildings for the elderly and the code for the design of buildings for elderly facilities. The architectural design data set also provides some reference data for the design of buildings for the aged [5]. There are many international scholars on the elderly building design research. Among them, Japan's research on building for the aged is at the world's leading level. For example, in the chapter of Japanese architectural design data integration: welfare and medical care, the existing elderly buildings in Japan are taken as examples to analyse various problems that should be paid attention to in the design of elderly buildings, which are worthy of our reference and research [6]. However, existing studies mainly focused on the declining physiological functions of the elderly and provide convenience for their daily behavior and activities, but seldom deal with the psychological and perceived comfort of the elderly. Therefore, based on existing studies, this paper designs experiments to study the correlation between auditory comfort and spatial scale of the main auditory dependent behavior of the elderly in living space, "watching TV", behavior from the perspective of perceived comfort.

2. Related Work

At present, the international studies on the establishment of space for the elderly to feel comfortable mainly include the relationship between people, environment and behavior, the construction of space suitable for aging and environmental perception theory. Alexander once mentioned in the language of architectural patterns that people's behavioral patterns and psychological needs in the face of different things in life are factors that cannot be ignored in the construction of home and outdoor behavioral patterns [7]. As for the relationship between environment and human, Japanese architect Ichihara Yoshinobu took scale and texture as the basic components of external space in his design of external space, and used rational data to conclude the importance of human perception and the environment and texture levels seen by people [8].

In addition, according to the research of relevant literature, the discussion on the design of suitable aging site started in developed countries such as Europe and America, which has been nearly 50 years ago. In terms of theory, in 1985, Diana. Y. Carstens wrote the first book, site planning and design for the elderly, which discussed site design methods based on the needs of the elderly [9]. In 2001, Rachel Cooper Marcus and Caroline Francis introduced the elderly outdoor area design in detail in their works. Other relevant monographs include environment and age, ecology and age, spatial behavior of the elderly,
etc., which respectively introduce the profound understanding of the aging problem in American society. Up to now, the research on suitable aging sites has involved in the relationship between activities and sites of the elderly, the relationship between site environment and cognitive state, the influence of landscape site elements on the elderly and their preferences and other fields. Japanese designer Shosuke Miyake proposed that by properly configuring the texture, colour, shape and other factors of the landscape facilities in the place to enhance the aging people's degenerate sensory stimulation, the elderly can more easily perceive the experience brought by the surrounding environment, so as to enhance their motivation to integrate into the society and increase the opportunity of interpersonal communication.

Therefore, in conclusion, as for the design of space for the elderly, scholars are gradually shifting their research direction to the common consideration of physiological and psychological environment. At present, the theory is more from the summary of experience and qualitative conclusions, but for quantitative analysis and experiment less research. This paper tries to use the methods of subjective interview and physiological index monitoring to provide new ideas for space design of sound environment suitable for aging from the perspective of qualitative and quantitative analysis, and to improve the current research situation.

3. Methods

The main factors that affect the old people's auditory perception include the sound pressure level of the sound source, the distance between the sound source and the old people and the clarity of the sound source. In the residential space of the building for the aged, the size and layout of the room will directly affect the elderly's perception of sound and understanding of the content of communication. Studies show that blindly increasing the sound pressure level of the sound source will harm the hearing of the elderly, which will aggravate the problems of tinnitus and deafness. Conversely, increasing the volume at a distance for the sake of the health of the auditory organs can interfere with the rest of the elderly in the surrounding rooms. Therefore, a reasonable hearing distance is essential for the elderly.

Based on this, we completed this study according to the technical route shown in Figure 1.

![Figure 1: Technology roadmap.](image)

3.1 Variable Control

This was a correlational study conducted during February and December in 2018. In this study, we started from the daily behaviors of the elderly to solve practical problems. First of all, we tracked and observed the behaviors and activities of the elderly for a week, the time and place of activities, and then summarized all the behaviors related to hearing in living space, and screened out the main behaviors related to hearing. Next, we will study these behaviors in detail. According to the survey of the elderly in the nursing home and access to information, the following behavior time table is summarized. We surveyed 60 elderly people, including 30 males and 30 females, all of whom were self-care seniors.
It can be seen from Table 1 that in the residential space, “TV watching” is the main auditory behavior of the elderly, and the time is concentrated in the period from dinner to sleep. The survey found that most of the elderly are used to sitting at the end of the bed watching TV. Therefore, the experiment was designed for the distance between the center of the pillow at the end of the bed and the TV.

Table 1: The elderly nursing home daily routine

<table>
<thead>
<tr>
<th>Schedule</th>
<th>5:00-6:00</th>
<th>6:00-7:00</th>
<th>7:00-8:00</th>
<th>8:00-11:20</th>
<th>11:20-12:00</th>
<th>12:00-13:30</th>
<th>13:30-16:20</th>
<th>16:20-17:00</th>
<th>17:00-19:30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedroom</td>
<td>get up</td>
<td>TV</td>
<td>sleep</td>
<td>TV</td>
<td>sleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restaurant</td>
<td>meal</td>
<td>meal</td>
<td>meal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Card room</td>
<td>chess</td>
<td>chess</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading room</td>
<td>exercise</td>
<td>exercise</td>
<td>exercise</td>
<td>exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before the experiment, considering that the participants' own conditions (age, education background, income and occupation) would affect the experiment and become experimental variables, the elderly selected were aged between 60 and 80 years old, those with a primary school education or above, and those with normal intelligence and understanding took care of themselves. In addition, considering that the hearing level of the elderly is different, we divided the participants into two groups, namely normal hearing group and slight hearing loss group (group was completed on the basis of professional hearing measurement), with 30 persons in each group and 15 persons in each gender, as shown in Table 2.

Table 2: The information of participants

<table>
<thead>
<tr>
<th>Listening level</th>
<th>Average listening level (dB HL)</th>
<th>The number of participants</th>
<th>Age</th>
<th>Sex ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>26-40</td>
<td>30</td>
<td>60-80</td>
<td>1:1</td>
</tr>
<tr>
<td>Impaired hearing</td>
<td>41-60</td>
<td>30</td>
<td>60-80</td>
<td>1:1</td>
</tr>
</tbody>
</table>

In total, we selected three pieces of audio that need to be played in the experiment, each of which is a one-minute audio (one-minute can cause the emotion to happen, and is the length of time that the human auditory attention is relatively concentrated). In order to reduce the influence of the audio content on the old people's emotions, the audio content is neutral without obvious rise and fall of emotional colour and intonation. As far as possible, the experiment guided the elderly to focus only on the effect of audio distance on sound articulation. The independent variable of this experiment is the distance between the subject and the audio. The audio volume should be fixed. Through data collection, we know that the volume value of TV is between 50-70dB, while over 60dB belongs to the category of noise. In addition, according to the "building code for the aged", the decibel value of daily living space is not allowed to exceed 55dB, so the audio volume is controlled at 50-55dB.

About the consideration of the distance between the horn and the participants in the experiment: the corridor space formed between the bed tail and the TV in endowment institutions is not less than 1050mm, and the thickness of the TV cabinet is 500-700mm. Therefore, the minimum distance between the bed tail and the TV is 1550mm, which is rounded to 1600mm in this experiment. In previous research found some living space because on the TV and bed around there are operation table, so will expand its distance to 3000 mm, so this study will consider change 3000 mm as the upper limit value, in the end, the experiment of the distance between 1600-3100m per every 300 mm, divided into six section of 1.6 m, 1.9 m, 2.2 m, 2.5 m, 2.8 m, 3.1 m; In addition, the order of audio playback was scrambled to avoid interference to the perception of the participants. As shown in Figure 2 and Figure 3.
3.2 Correlation Analysis of Auditory Comfort and Spatial Scale

Ergo-lab technology platform was used to record physiological signals (skin electrical signals and pulse signals) of the elderly.

Electrodermal activity (EDA) represents the epidermal potential induced by endogenous or exogenous stimulation and reflects the functional status of post-ganglionic fibers of sympathetic nerves. It is a relatively objective and sensitive physiological index. When a person is mentally stressed or in a state of heightened mental activity, the body is "sweating" or "sweating." This is because emotional stimuli trigger a response in the autonomic nervous system, which in turn produces a response in the sweat glands. If the sympathetic nervous system is highly stimulated, sweat gland activity also increases, which in turn increases skin conductance, as evidenced by an increase in the difference between the skin conductance signal and the mean value of the elderly's calm time signal. In this way, skin conductance measures emotional and sympathetic responses. Accurately recording the psychological changes of the elderly at each moment improves the accuracy and credibility of the subjective questionnaire.

Photo Plethysmo Graphy (PPG) represents photoelectric volume pulse, which presents comprehensive information of shape, intensity, rate and rhythm, etc, reflecting human blood flow characteristics to a large extent. The pulse signal of the aged can be recorded and monitored continuously through the sensor. The collected total energy value (TP), the ratio of low frequency to high frequency (LF/HF), high frequency (HF) and low frequency (LF) data can be used to reflect the emotional state and degree of consciousness awareness of the elderly.

Experimental process:
(1) Participants were seated in pilot A, and PPG and EDA physiological sensors were worn on their earlobes and palms.

(2) Participants were asked to stabilize their emotions and relax for 5 minutes, and the physiological data baseline values of the subjects were collected.

(3) The sound source was randomly placed at b1-b6, and the prepared audio file was played successively with a volume of 55dB. During the experiment, physiological data of the subjects were continuously collected.

(4) At the end of each audio group, there is a minute for preparation. During this period, we will ask the elderly to rate the comfort level of the sound they hear (full score of 5).

The evaluation method of 'Likert scale '5-level scale is adopted, as shown in Table 3.

<table>
<thead>
<tr>
<th>score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>describe</td>
<td>Very uncomfortable</td>
<td>More uncomfortable</td>
<td>general</td>
<td>comfortable</td>
<td>very comfortable</td>
</tr>
</tbody>
</table>

After the experiment, the evaluation results and data results were integrated and analysed. Through the analysis of SPSS software, we found that in the elderly group with good hearing, the correlation coefficient $P=0.285$, the auditory comfort and distance are not significantly correlated, while in the elderly with poor hearing, the auditory comfort and distance $P<0.01$, there is a significant correlation, as shown in Table 4.

<table>
<thead>
<tr>
<th>Listening level</th>
<th>Pearson Correlation (r)</th>
<th>Sig (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>the elderly group with normal hearing</td>
<td>-0.076</td>
<td>0.285</td>
</tr>
<tr>
<td>the elderly group with impaired hearing</td>
<td>-0.578</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### 3.3 Physiological Data Analysis

In the experiment, the Ergo-LAB platform was used to monitor the skin electrical response (EDA) and pulse signal (PPG) of the elderly under different acoustic conditions. The platform analysed the physiological data of 60 subjects. First determine their EDA and PPG baseline values in a relaxed and calm state. Then, the ratio of the change value of the data value at the six experimental points to the baseline value, $\Delta i (\Delta i =(ai-a0)/a0)$, was calculated. We compared the data of EDA and PPG at each time period to speculate the psychological changes of the elderly at the corresponding time period, and finally confirmed the optimal auditory distance by combining subjective scoring and interviews. The following Figure 4 and Figure 5 respectively show the process of software data collection and analysis.
4. Results

In the experiments of the two groups of elderly people, 1.6m and 3.1m are two distances with large fluctuation of signal changes, among which the elderly with poor hearing have the largest fluctuation of 1.6m, while the elderly with good hearing have the largest fluctuation of 3.1m. By observing the broken line graph of the two groups of data, the overall trend of symmetry is also presented. Combined with subjective scoring, 1.6m and 3.1m are the distances between the two groups with large emotional fluctuations. Through subjective interviews, we preliminarily concluded that the elderly with poor hearing had difficulty in hearing of 3.1m, which was reflected as increased pressure. 1.6m is psychologically closer and more comfortable. However, for the elderly with good listening ability, the subjective scoring showed no obvious preference trend, but more dependent on personal habits. In terms of data reflection, the closer and the longer distance are still the two groups that cause more obvious perception and emotion.

In the two groups of elderly people, the sympathetic and parasympathetic nerves showed no obvious change trend in each distance of the experiment, and the overall emotional arousal degree was relatively stable. In addition, combined with the interview, we found that the TP values of the two groups of elderly people were lower in the near and distant values, and their attention was more focused. In which an elderly person with poor hearing has a higher attention on the distance of 2.5m, as shown in Figure 6 and Figure 7.

After summarizing the above data analysis results, we preliminarily draw a conclusion that in the behavior of watching TV, for the elderly with poor hearing, a distance of 1.6m is more appropriate. For the elderly with good hearing, both 1.6m and 3.1m are popular distances, and individual differences have great influence, without obvious difference in perceived comfort. In addition, both groups of older adults showed higher levels of attention at closer and longer distances.

Figure 6: The change trend of TP, LF and HF values of pulse signals in normal hearing and hearing-impaired elderly.

Figure 7: The change trend of skin conductance signals in normal hearing and hearing impaired elderly people.
5. Conclusions

This study combines subjective evaluation and comprehensive analysis of physiological indicators in an exploratory way, so as to avoid the interference of subjective factors on experimental results. At present, the design of the experiment is not perfect enough, and there is still a lot of room for improvement, including the influence of wearing sensors on the psychology of the elderly, as well as the influence of visual interference in the experimental environment and audio material, which need to be further improved. The number of participants in this experiment is limited, and the conclusion still needs further verification.

However, from the new perspective, we obtained the appropriate distance for the elderly to feel comfortable when watching TV. The result may provide some dimensional references for the future design of elderly building space. In addition, continuing this line, we can also explore other aspects of elderly people's vision, touch, temperature perception and comfort in the future design of elderly architectural space.

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