

Design of Proton Radiotherapy Room Based on Environmental Psychology

Zikun Gao and Xinxiong Liu

Industrial Design, School of Mechanical Science & Engineering, Huazhong University of Science and Technology, Wuhan, China

ABSTRACT

Proton radiotherapy is currently a more advanced tumor treatment method in radiotherapy, which can accurately eliminate tumor cells while reducing damage to surrounding healthy cells. However, anxiety and depression often occur in cancer patients during treatment. On the one hand, it will cause the displacement of the lesion and affect the effect of radiotherapy. On the other hand, negative psychology is not conducive to physical rehabilitation. In this paper, the principle of environmental psychology is used to guide the design of indoor environment of radiotherapy from the perspective of visual and auditory senses. Through the influence of environment on psychology, the purpose of calming the mood of patients and improving the therapeutic effect is achieved, and it provides support and reference for the design of humanized radiotherapy room space in the future.

Keywords: Environmental psychology, Proton radiotherapy room design, Patient psychology

INTRODUCTION

Cancer has become one of the major public health problems that seriously threaten the health of Chinese population. But in the course of treatment, 30% to 50% of cancer patients suffer from anxiety and depression due to concerns about their condition, which largely affects the effectiveness of cancer treatment. On the one hand, the tightness of the muscles caused by tension will cause the actual tumor location deviation, resulting in radiotherapy deviation. On the other hand, a negative psychological state can affect the development of the disease through multiple systems in the body and is very detrimental to treatment and recovery. Depression can increase mortality by 39 % in adult cancer populations. Therefore, in the treatment of cancer patients, it is necessary to consider how to alleviate their depression and help them build confidence so as to improve the therapeutic effect.

THE INFLUENCE OF ENVIRONMENT ON PSYCHOLOGY

Concept of Environmental Psychology

Environmental psychology theory is about the relationship between human and environment. As the object of the environment and the subject of creating the environment, the environment plays a role in People's behavior patterns

and psychological activities. The application of environmental psychology in interior design is the effect and influence of interior space layout, space color and decorative elements on human psychology, and then study the psychological changes and reactions caused by the environment (Xilei Hu, 2018).

Using Environmental Psychology to Change Patients' Psychology

For proton therapy centers, radiotherapy indoor environment has a great impact on patients. The environment is special. The space of radiotherapy room is empty and needs to be completely closed during radiotherapy; the treatment equipment inside is large and bulky, with a strong sense of oppression and a loud noise during operation. Such an environment is not conducive to easing the tension of patients.

Relaxing calm emotion is conducive to making the actual treatment area of patients in the radiotherapy process more consistent with the target area, and establishing a firm confidence in treatment, which has a positive effect on treatment and recovery. Therefore, it is necessary to scientifically establish a mental environment efficacy model for cancer patients based on environmental psychology. According to the patients' personal state, to transform and adjust the color, material, sound, light and other aspects, to create a treatment equipment environment for patients, immediate preference, positive adjustment of patients mentality, with proton radiotherapy and related medical services, improve the therapeutic effect.

APPLICATION OF ENVIRONMENTAL PSYCHOLOGY IN PROTON RADIOTHERAPY ROOM DESIGN

Radiotherapy is one of the important means to treat cancer. As the most advanced new mode of tumor treatment recognized by the global medical community, proton beam has its unique physical characteristics – Bragg peak, compared with photon and electron rays used in conventional radiotherapy. Based on this feature, proton beam energy releases can be more concentrated in the tumor site, with normal tissues in front of the tumor, including skin, exposed to lower doses, while normal tissues after the tumor are exposed to almost zero doses. Therefore, proton therapy will bring better tumor control rate and lower incidence of normal tissue complications, and the comprehensive radiotherapy effect is better.

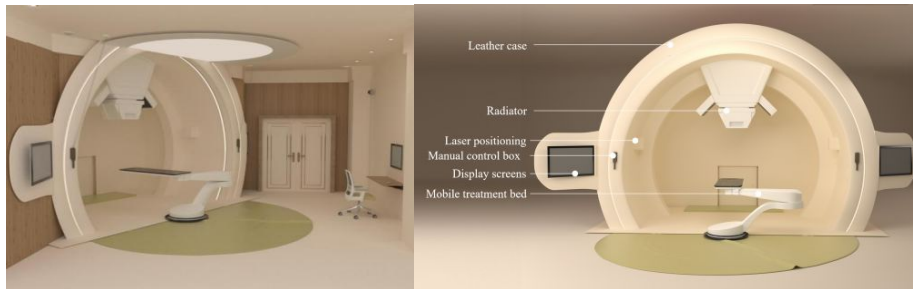
The project comes from The National Key Research and Development Program of China (No. 2016YFC0105306). This paper uses the proton radiotherapy room as a practical example of design to investigate how environmental psychology can be used to guide the design of radiotherapy spaces in order to reduce patients' negative emotions of anxiety and depression during treatment, thereby enhancing treatment outcomes. According to environmental psychology, people are affected by the outside world through the five senses of sight, hearing, smell, taste and touch. This paper focuses on the visual and auditory aspects.

Visual Aspect

1. **Color Environment.** Color has an important impact on the psychological and emotional well-being of people. Experiments have verified that when the human eye looks at colors, its pulse, respiration, brain waves, etc. will all change due to different colors. (Hui Zhu and Yudong Zhang, 2008). For example, a red environment will make people feel joyful, enthusiastic and exuberant, while a blue environment will make people feel calm, distant and open. Conventional radiotherapy room spaces are often color-coordinated with a white background and decorated with individual warm or cool shades. When designing the indoor color of proton radiation therapy, a dominant color phase with a large area can be selected, and a regulatory color with a high color degree can be selected with a small area. Use a color palette of less than three colors, as more than three colors can be difficult for the eye to accept. Avoid using low brightness colors that make the patients feel tense and oppressed. Pale yellow can be used as the main color to make patients feel relaxed, open and happy (Yuanqin Wu, 2005).
2. **Lighting Environment.** Light is a necessary condition for the formation of visual work. It controls the circadian rhythm, and affects people's emotions and cognition. It is closely related to physical health (Kun Zeng and Luoxi Hao, 2016). A light environment with low color temperature and low illumination (2 700 K, 100 lx) is more relaxing than a environment with medium-high color temperature and high illumination (4 000 K, 1 300 lx) (Luoxi Hao et al. 2017). When radiotherapy is performed in the room, keeping the lighting design to low color temperature and low illumination is more conducive to the emotional stability of the patients. In the treatment process, there are situations where doctors need high-intensity lighting such as debugging instruments for patients, so an adjustable illumination system can be used to meet different needs in different situations. Patients tend to feel drained while waiting before treatment. Lying facing the light source on the ceiling can also cause some pressure on them. Their attention can be diverted by projecting videos they like on the ceiling with lights to relieve tension.

Auditory Aspect

1. **Noise Reduction.** Noise is associated with various functional disorders of the human body. The psychological impact of noise on people is highlighted by their mood (Li Shu, 2007). When the noise exceeds 60 dB, the disturbance generated by the environment can cause irritability, anxiety and depression (Hong Jiang et al. 2008). Radiotherapy machines make loud noises that need to be dealt with. There are two ways to reduce the impact of noise. One is to intervention in the transmission process. It can be done by using professional sound-absorbing and sound-insulating materials in the renovation process, with a double intervention to isolate the noise. Another one is to increase the transmission source. Another



Figures 1 and 2: Interior view of radiotherapy room.

source of music can be added as a masking sound to divert the patients' attention from the noise, while creating a calmer and more relaxed atmosphere for the patients.

2. **Music playback.** Music can effectively reduce patients' anxiety. Musical sound waves cause the body to secrete substances such as hormones that are beneficial to health through the regulation of nerve and neurological fluids (Guangrong Cai, 2001). Different patients have different life experiences and cultural backgrounds and have different preferences for music, so different types of music can be offered to patients in order to maximize the effect of it on mood. Some nature sounds such as the sea, breeze and streams can reduce the patients' anxiety level even more than ordinary music, even during the short period of radiotherapy (Largo-Wight E. et al. 2016).

PROTON RADIOTHERAPY ROOM DESIGN

Presentation of Design Results

The design hopes to provide a comfortable treatment environment for patients by enhancing the sense of home in the radiotherapy room. Reducing their anxiety and depression in order to enhance the outcome of cancer treatment.

In terms of vision, as shown in Figure 1 and 2, a large area of beige is used as the main color, supplemented by wood grain brown and small area of green. The beige makes the patients feel relaxed, the wood-grain brown adds a sense of intimacy and the green gives the patients a sense of hope. The combination of the three is warm and comfortable, with a more homely feel. The interior of the treatment chamber is upholstered in leather, effectively replacing the coldness of conventional medical instruments with a softer, more comfortable and approachable feel.

As shown in Figure 3, a light source system with adjustable illumination levels is used to increase the level when doctors needs it and to maintain low level during treatment. Patients need to go through a long process of positioning before treatment, when a video of the patients' preferences is projected on the ceiling to help ease their nerves.

In terms of hearing, to reduce the impact of instrument operation noise on patients, both sound-absorbing and sound-insulating features are used on

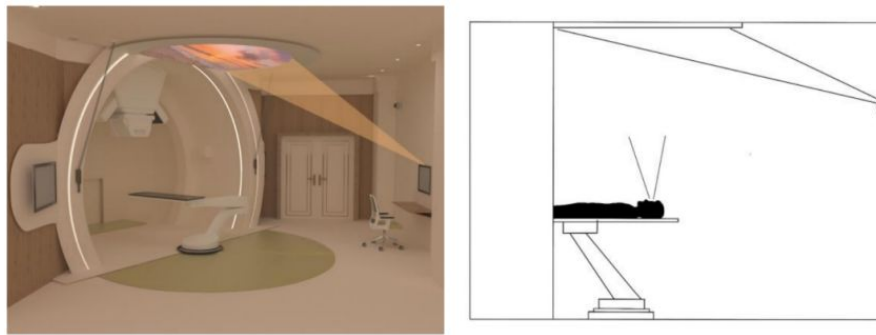


Figure 3: Lighting system for radiotherapy room.

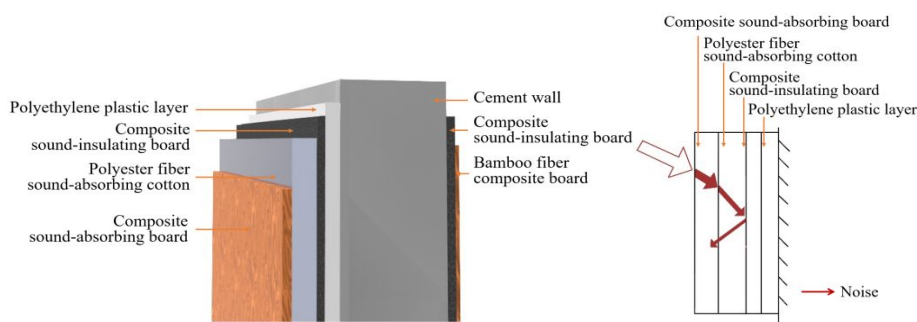


Figure 4: Sound-absorbing and sound-insulating materials.

the walls. As shown in Figure 4, from the outside to the inside are composite sound-absorbing board, polyester fiber sound-absorbing cotton and composite sound-insulating board. And noise reduction devices are installed on both sides of the rotating cabin. Play soft music that patients are familiar with and love during radiotherapy, which not only masks the noise, but also soothes the patients' mood.

In addition to the senses of sight and sound, the design also takes into account the patients' sense of touch and smell. The material chosen for the radiotherapy bed and the radiotherapy chamber wrapping is the PP material commonly used for medical equipment, increasing the hardness of the equipment shell while providing a degree of toughness. Set up a ventilation system and use air disinfection machines to reduce odor, keep the air clean and avoid cross-contamination.

ASSESSMENT OF DESIGN PRACTICE

After completing the design of the proton radiotherapy room, a validation experiment was designed to assess whether the final design outcome met the aim of reducing patients' anxiety.

1. Participants. A total of 40 participants were tested, including 20 radiotherapy professionals and 20 radiotherapy patients in Wuhan Union Hospital of Hubei Province, China.

Table 1. Normality test of verification questionnaires.

	Kolmogorov-Smirnov (V) ^a			Shapiro-Wilk		
	statistics	df	significance	statistics	df	significance
Reduction of anxiety in the pre-test	.269	40	.001	.817	40	.002
Reduction of anxiety in the post-test	.253	40	.002	.835	40	.003
Home atmosphere in the pre-test	.218	40	.013	.849	40	.005
Home atmosphere in the post-test	.291	40	.000	.774	40	.000
Reduction of loneliness in the pre-test	.202	40	.031	.918	40	.092
Reduction of loneliness in the post-test	.334	40	.000	.678	40	.000
Reduction of claustrophobia in the pre-test	.180	40	.089	.905	40	.052
Reduction of claustrophobia in the post-test	.273	40	.000	.759	40	.000

(a. Lilliefors Significance Correction).

2. Experimental Materials. The experimental materials include a video of the interior design effect of the proton radiotherapy room and two questionnaires. Questionnaires were used to evaluate the existing proton radiotherapy room environment and the proton radiotherapy room environment designed in this paper. Both questionnaires asked the same questions and were scored using the six-point Richter scale ranging from “strongly disagree” (1 point) to “strongly agree” (6 points).
3. Test program. This experiment consists of two parts: pre-test and post-test. The participants evaluated the existing proton radiotherapy room environment and the proton radiotherapy room environment designed in this paper, respectively.
4. Experimental results. The normality test was performed on both pre-test and post-test questionnaire. If the data in both groups were smaller than the normal distribution, the paired sample T test was selected, otherwise, the paired sample rank sum test was selected. As shown in Table 1, since this experiment was a small sample normality test with a sample size of less than 100, observing the Shapiro-Wilk test data, all four sets of pre-test and post-test data had at least one column of data with a significance less than 0.05, so the paired sample rank sum test was chosen.

The four groups of data were analyzed by paired sample rank sum test. As shown in Table 2, the significance of the four groups of data were all less than 0.05, indicating that there was a significant difference between the pre-test and post-test data of this experiment.

The nonparametric test mainly compares the difference between the pre- and post-test by testing the median size of the two columns of data. The analysis shows that the medians of the pre-test and post-test in the four groups of data are respectively 3.00 and 5.00, 2.00 and 5.50, 3.00 and 6.00, 3.00 and

Table 2. Test statistics of verification questionnaires.

	Reduction of anxiety in the pre-test/in the post-test	Home atmosphere in the pre-test/in the post-test	Reduction of loneliness in the pre-test/in the post-test	Reduction of claustrophobia in the pre-test/in the post-test
Z	-3.765 ^b	-3.868 ^b	-3.693 ^b	-3.543 ^b
Asymptotic Significance (2-sided)	.000	.000	.000	.000

a. Wilcoxon signed-rank test.

b. Based on negative rank.

5.50. The post-test medians of the four groups of data were all larger than the pre-test medians. It can be seen that the design effect of this paper is significantly higher than that of general radiotherapy space in reducing patients' anxiety.

According to the results of the validation experiment, the design practice based on environmental psychology principles in this paper can achieve the purpose of reducing patients' anxiety and improving treatment outcomes.

CONCLUSION

Proton radiotherapy, as a current advanced technology for oncology treatment, has good prospects for development. In addition, the design of radiotherapy room space based on environmental psychology is of great significance to improve the treatment outcome by alleviating patients' anxiety and depression during radiotherapy. It is hoped that the research in this paper will provide support and assistance in designing a psychologically appropriate and humane radiotherapy room space for patients.

REFERENCES

- Guangrong Cai, Yi Qiao, Peiwen Li, Liping Jiao, Ying Hao, Luliang Xu. (2001). Clinical Application of Music Therapy in Oncology. *Chinese Mental Health Journal*, 2001(03), 179-181.
- Hong Jiang, Shuguang Li, Huaye Liu, Jiemin Huang. (2008). *Investigation and Analysis of Noise in General Hospitals*. *Chinese Nursing Management*, 2008(03), 37-39.
- Hui Zhu, Yudong Zhang. (2008). Research on Color Psychology Based on Experimental Psychology. *China Packaging Industry*, 2008 (07), 48-51.
- Kun Zeng, Luoxi Hao. (2016). Exploration of Light and Emotional Experiment Methods Suitable for Healthy Lighting Research. *China Illuminating Engineering Journal*, 2016 27(05), 1-8.
- Largo-Wight E, O'Hara B K, Chen W W. (2016). The Efficacy of a Brief Nature Sound Intervention on Muscle Tension, Pulse Rate, and Self-Reported Stress: Nature Contact Micro-Break in an Office or Waiting Room. *HERD*. 2016, 10(1).
- Li Shu. (2007). Research on Noise in Environmental Psychology and the Revision of Mood Scale. Beijing Forestry University.

-
- Luoxi Hao, Yixiao Cao, Zhe Cui, Kun Zeng, Rongdi Shao. (2017). Research Trends and Application Prospects of Light and Health. *China Illuminating Engineering Journal*, 2017 28 (06), 1–16.
- Xilei Hu. (2018). Exploration of the interior space design of environmental psychology in the medical simulation training center. *Chinese and Overseas Architecture*, 2018 (09), 182–185.
- Yuanqin Wu. (2005). The Psychological Effect of Color and its Application in Design. *Fujian Architecture*, 2005 (Z1), 4–5.