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THE PSYCHOLOGICAL EFFECTS OF DIFFERENT TYPES OF HOUSING ENVIRONMENT UNDER DIFFERENT WEATHER CONDITIONS

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ABSTRACT

In order to improve the quality of human being's living and working environment, different types of wood structure building, ecological architecture and green building are advocated due to their lots of advantages. This study compared three types of houses in different weather conditions on people's psychological and physiological indexes. The results showed that the temperature, electrocardiograph, heart rate and respiratory rate of people in different types of housing environment are different. Most of the physiological indexes in structural glued laminated and wood structure environment were better than those in steel and concrete structure environment, and most of the physiological indexes in structural glued laminated environment were better than those in the timber structure environment. It means that subjects of the test are easy to had comfortable and relaxed feeling in the glued laminated and timber structure environment. This provided theoretical support for the use of the product by scientific and efficient ways, and guidance for design and application of the construction of the wooden structure environment in the future.

KEYWORDS: Housing environment; wooden buildings; living environment; psychological effect.

INTRODUCTION

Wood is available in most countries as a versatile and naturally replenishable resource of raw material (Nyrud and Bringslimark 2010). Along with the progress of the times, development of economy and technology, and deepening of scientific research, wood resources would be utilized scientifically and effectively when people have more pursuit and creation for the architectural environment. China has a very long history of wooden buildings, and the environment-friendly characteristics of wooden structures are highly esteemed. Today, many residential homes and some commercial and industrial buildings are constructed using modern wood frames, and in the future it is likely that more people will be interested in various types of construction and transport that employ wood (James and Wacker 2010). Therefore, the development of wood-frame buildings should exploit the engineering capacity of wood products, enhance the production of wood resources, and utilize the environment-friendly characteristics of wood. The use of wood helps save resources and promotes environmental protection.

As sedentary and service-related work in the indoor environment become more prevalent in our society, the average time for person spends indoors increases, which makes the design and decoration of the interior environment ever more important. However, as the time flies and the green building and new design strategies have been expanded, people's understanding of human's health now include not only our physical condition but also our psychological well-being (Nyrud et al. 2008).

So far, certain progress and achievements have been made by scholars in the characteristics of psychology, physiological and its environment with wood (Yamada 1987, Nakamura and Takachio 1960, Nakamura and Masuda 1995, Masuda 1992, Nakamura et al. 1996, Liu et al. 2003). Nakamura and Masuda (1990) studied the influences of groove intervals on the psychological images of wooden wall panels. When the wood texture stimulate the visual perception of human, it can give the rhythm feeling about movement and the life, the natural feeling about harmony and fluent to people, and made people have feel comfortable and relaxed (Zhao 1997). Different physiological responses in the room with an ordinary interior design caused a calm and relaxed state, while the other room with visible wooden posts and beams caused an active and aroused state (Tsunetsugu et al. 2005). Therefore, scientists have now confirmed that this sensation of relaxation and nature is due to a reduction in stress reactivity in our sympathetic nervous system, and the visual effects of wooden materials on the autonomic nervous activities. This is both psychologically and physiologically beneficial for those in contact with nature.

Wood-frame building has its specific cultural background, which is the important element in the traditional architectural culture, and closely related to people's living environment, way of life and the work environment. Architectural technology, performance, and the artistic image of space for wood-frame building are important, but the final purpose is to provide human activity sites and fully embody its functionality. So, wood-frame buildings create wooden environment only by people activity test for living meaningful; it must be taken into account the psychological interaction relationship between people and the environment. It doesn't have a scientific and accurate definition about roles and regularity of different structural factors and characteristic parameters of wood construction environment for the comfortableness, habitability and health of human life. Wood-frame building is both a comprehensive space environment, and an ecosystem with people-centric. Perception of the environment is reflected through the people's behavior and psychology, which include both the physical environment and psychological environment. Therefore, efforts on developing wood-frame buildings using ecological designs in terms of sustainable development have to take into consideration with physical, psychological, and human

physiological factors. In this regard, it is necessary to study physiological indexes which affect the architectural environment (Tsunetsugu et al. 2007).

MATERIAL AND METHODS

The subjects were carried out by 20 volunteers (10 male, 10 female) from different trade backgrounds. The average age of the volunteers was 27.15 years, and ages ranged from 25 to 35 years. This experiment at the low carbon demonstration was exhibited in Suzhou Crownhomes CO., LTD in China. The time was chosen from October to December. Three different building types for the subjects were chosen to be used for the procedure of the experiment (Fig. 1-3). Fir imported from USA with wood surface treated by sealants was used as log structure housing materials. Glulam structure housing materials used SPF (Douglas fir and spruce), with the Japanese indoor decorative style. The main decoration wooden materials of reinforced concrete structure housing is wood furniture and floors. The proporation of the wooden decoration materials used in log, glulam, and reinforced concrete structure housing materials to total decoration materials used are 90, 70, and 20 %, respectively. The psychological tests were conducted in three different building rooms with three different weather condition (sunny day, cloudy day, rainy day), respectively. The area of these buildings is basically the same, and the proportion of wood interior decoration as shown in Fig.1-3.

The experimental apparatus was CAPTIV (Fig. 4). This experiment records and tests the physiological indexes of subjects by CAPTIV behavior analysis system synchronous. Six wireless sensors (Temperature (skin temperature), GSR (skin conductance), EMG (electromyography), ECG (electrocardiograph), Respiration, CFM (heart rate)) were located at the trunk and arm parts of the subjects respectively (Fig. 4).

Fig. 1: Log structure. (95 % wooden decoration).

Fig. 2: Glulam structure. (75 % wooden decoration).

Fig. 3: Reinforced concrete structure. (25 % wooden decoration).

Fig. 4: CAPTIV behavior synchronous analysis diagram.

The orders of trials were randomized for each participant. Subjects were respectively into the house of three different types, in order to complete four tasks of sit, walk, climb stairs, and looking (look at the pictures), Each task spent 2 min in three kinds of weather conditions. In addition, each experiment lasted at least 10 min or more time (if required). To ensure that individual physiological indexes returned to baseline levels provided a rest period between 10 min (you may extend if desired) was given between each experiment.

RESULTS AND DISCUSSION

In the wood structure housing

The experimental results showed that main effect on skin temperature differences in weather conditions was significant (F=10.268, p<0.05) (Tab. 1), while the main effect on skin conductance difference was not significant (F=0.217, p>0.05). And the main effect on EMG was also significant (F=3.411, p<0.05), but the main effect on ECG was not significant (F=2.190, p>0.05). The main effect on respiratory difference was not significant (F=1.339, p> 0.05) too. And the main effect on the heart rate was significant (F=3.485, p< 0.05).

Tab. 1: Physiological indicators data of log structure house under different weather conditions (M±SD).

Physiological indicators	Sunny	Cloudy	Rainy
Temperature (°C)	27.522±0.366	29.890±0.369	28.952±0.366
GSR (μS)	2.312±0.128	2.299±0.144	2.426±0.156
EMG (μV)	18.165±3.513	13.623±3.513	26.418±3.513
ECG (μV)	-0.267±0.022	-0.322±0.022	-0.322±0.022
Respiration (%)	90.333±0.802	89.910±0.802	91.686±0.802
CFM (BMP)	83.946±1.489	89.293±1.489	85.299±1.489

The main effect of various conditions on the task conditions was given in Tab. 2. We can couclude that the main effect on skin temperature in different task states was not significant (F=0.666, p> 0.05); the main effect on skin conductance difference was not significant (F=0.788 p> 0.05); the main effect on EMG was significant (F=3.313, p< 0.05); the main effect on ECG was not significant (F= 0.206, p> 0.05); the main effect on the respiratory difference was significant (F=9.825 p<0.05); the main effect of the heart rate was significant (F=51.004, p<0.05).

Tab. 2: Physiological indicators data of log structure house under different task conditions (M±SD).

Physiological indicators	Sit	Walk	Climb stairs	Looking
Temperature (°C)	28.344±0.427	28.991±0.423	28.724±0.423	29.133±0.423
GSR (μS)	2.229±0.143	2.229±0.159	2.534±0.176	2.391±0.180
EMG (μV)	13.820±4.056	24.643±4.056	26.811±4.056	12.333±4.056
ECG (μV)	-0.305±0.025	-0.318±0.025	-0.300±0.025	-0.291±0.025
Respiration (%)	94.666±0.926	88.776±0.926	88.288±0.926	90.842±0.926
CFM (BMP)	73.933±1.720	86.020±1.720	103.001±1.720	81.763±1.720

The main effect of various conditions on the gender was given in Tab. 3. We can couclude that the main effect on the skin temperature in gender was significant (F=41.109, p< 0.05); the

main effect on skin conductance difference was not significant (F=0.514, p> 0.05); the main effect on EMG was not significant (F=0.467, p> 0.05); the main effect on ECG was not significant (F=1.314, p>0.05); the main effect on the respiratory difference was significant (F=92.457, p<0.05); the main effect on the heart rate was significant (F=20.138, p<0.05).

Tab. 3: Physiological indicators data of log structure house under different gender (M±SD).

Physiological indicators	Male	Female
Temperature (°C)	27.440±0.299	30.156±0.300
GSR (μS)	2.405±0.101	2.287±0.130
EMG (μV)	20.787±2.868	18.016±2.868
ECG (μV)	-0.318±0.018	-0.289±0.018
Respiration (%)	95.093±0.654	86.193±0.654
CFM (BMP)	83.946±1.530	89.293±1.530

The interaction between weather conditions and the state of the task on the skin temperature main effect was not significant (F=0.176, p>0.05); The main effect on skin conductance difference was not significant (F=0.416, p>0.05); The main effect on EMG was not significant (F=0.654, p> 0.05); The main effect on ECG was not significant (F=0.985, p>0.05); The main effect on the respiratory difference was not significant (F=0.051, p> 0.05); The main effect on the heart rate was not significant (F=0.796, p> 0.05).

The interaction between weather conditions and gender differences on the skin temperature main effect was significant (F=10.803, p<0.05); The main effect on the skin conductance difference was significant (F=5.950, p<0.05); The main effect on EMG difference was not significant (F=1.576, p>0.05); The main effect on ECG was not significant (F=0.273, p>0.05); The main effect on heart rate difference was not significant (F=0.869, p>0.05); The main effect on the respiratory difference was significant (F=3.200, p<0.05).

The interaction of weather conditions, state of task and gender on the skin temperature main effect difference was not significant (F=0.484, p>0.05); The effect on skin conductance difference was not significant (F=0.680, p>0.05); The effect on EMG difference was not significant (F=0.216, p>0.05); The effect on ECG was not significant (F=1.186, p>0.05); The effect on respiratory difference was not significant (F=0.062, p>0.05); The main effect on the heart rate was not significant (F=0.321, p>0.05).

In glulam structure housing

The main effect on skin temperature differences in weather conditions was significant (F=10.509, p<0.05) (Tab. 4); The main effect on skin conductance difference was not significant (F=0.146, p>0.05); The main effect on EMG was significant (F=3.600, p<0.05); The main effect on ECG was significant (F=4.823, p<0.05); The main effect on respiratory difference was not significant (F=1.924, p>0.05); The main effect on the heart rate was significant (F=5.448, p<0.05).

The main effect of various conditions on the task conditions was given in Tab. 5. We can couclude that the main effect on the skin temperature in different task states was not significant (F=0.302, p>0.05); The main effect on skin conductance difference was not significant (F=1.004, p>0.05); The main effect on EMG was significant (F=4.132, p<0.05); The main effect on ECG was not significant (F=0.297, p>0.05); The main effect on respiratory difference was significant (F=4.979, p<0.05); The main effect on the heart rate was significant (F=39.286, p<0.05).

Tab. 4: Physiological indicators data of glulam structure house under different weather conditions (M±SD).

Physiological indicators	Sunny	Cloudy	Rainy
Temperature (°C)	29.313±0.335	31.483±0.335	30.388±0.335
GSR (μS)	2.269±0.168	2.212±0.193	2.367±0.214
EMG (μV)	20.135±2.166	12.429±2.166	18.756±2.166
ECG (μV)	-0.174±0.029	-0.256±0.029	-0.302±0.029
Respiration (%)	87.063±0.750	86.162±0.750	88.235±0.750
CFM (BMP)	82.632±1.620	89.771±1.620	84.036±1.620

Tab. 5: Physiological indicators data of glulam structure house under different task conditions (M±SD).

Physiological indicators	Sit	Walk	Climb stairs	Looking
Temperature (°C)	30.169±0.387	30.626±0.387	30.516±0.387	30.267±0.387
GSR (μS)	2.286±0.210	1.940±0.256	2.458±0.212	2.447±0.207
EMG (μV)	13.163±2.501	18.625±2.501	23.646±2.501	12.993±2.501
ECG (μV)	-0.266±0.034	-0.237±0.034	-0.251±0.034	-0.223±0.034
Respiration (%)	89.165±0.865	85.433±0.865	85.570±0.865	88.447±0.865
CFM (BMP)	75.441±1.871	85.207±1.871	102.006±1.871	79.265±1.871

The main effect of various conditions on the gender was given in Tab. 6. We can couclude that the main effect on skin temperature in gender was significant (F=34.654, p<0.05); The main effect on skin conductance difference was not significant (F=0.305, p>0.05); The main effect on EMG difference was not significant (F=0.608, p>0.05); The main effect on ECG was not significant (F=0.193, p>0.05); The main effect on the respiratory difference was significant (F=87.211, p<0.05); The main effect on the heart rate was significant (F=11.548, p<0.05).

Tab. 6: Physiological indicators data of glulam structure house under different gender (M±SD).

Physiological indicators	Male	Female
Temperature (°C)	29.257±0.273	31.532±0.273
GSR (μS)	2.344±0.138	2.221±0.174
EMG (μV)	18.081±1.768	16.132±1.768
ECG (μV)	-0.252±0.024	-0.237±0.024
Respiration (%)	91.195±0.612	83.112±0.612
CFM (BMP)	82.301±1.323	88.659±1.323

The interaction between weather conditions and states of task on the skin temperature main effect was not significant (F=0.127, p>0.05); The main effect on skin conductance difference was not significant (F=0.434, p>0.05); The main effect differences on EMG was not significant (F=0.526, p>0.05); The main effect on ECG was not significant (F=0.941, p>0.05); The main effect on the respiratory difference was not significant (F=0.016, p>0.05); The main effect on the heart rate was not significant (F = 0048, p>0.05).

The interaction between weather condition and gender differences on the skin temperature main effect was significant (F=18.659, p<0.05); The main effect on skin conductance difference was not significant (F=0.744, p>0.05); The main effect on EMG was significant (F=3.934, p>0.05); The main effect on ECG was not significant (F=0.533, p>0.05); The main effect on

respiratory difference close to the edge was significant (F=2.885, p=0.058); The main effect on the heart rate was not significant (F=0.974, p>0.05).

The interaction of weather conditions, state of task and gender on skin temperature main effect was not significant (F=0.473, p>0.05); The main effect on skin conductance difference was not significant (F=0.253, p>0.05); The main effect on EMG was not significant (F=0.945, p>0.05); The main effect on ECG was not significant (F=0.677, p>0.05); The main effect on respiratory difference was not significant (F=0.160, p>0.05); The main effect on the heart rate was not significantly (F=0.776, p>0.05).

In reinforced concrete structure housing

The main effect on skin temperature differences in weather conditions was significant (F=11.377, p<0.05) (Tab.7); The main effect on skin conductance difference was not significant (F=1.999, p>0.05); The main effect on EMG close to the edge was significant (F=2.915, p=0.056); The main effect on ECG significant (F= 450, p<0.05); The main effect on respiratory difference was not significant (F=2.815, p>0.05); The main effect on the heart rate was significant (F=3.793, p<0.05).

Tab. 7: Physiological indicators data of reinforced concrete structure house under different weather conditions (M±SD).

Physiological indicators	Sunny	Cloudy	Rainy
Temperature (°C)	28.458±0.298	30.360±0.298	29.972±0.298
GSR (μS)	2.121±0.153	2.509±0.159	2.089±0.202
EMG (μV)	17.586±1.910	12.813±1.910	19.049±1.910
ECG (μV)	-0.137±0.040	-0.292±0.040	-0.276±0.040
Respiration (%)	86.494±0.690	85.834±0.690	88.086±0.690
CFM (BMP)	87.478±1.547	92.546±1.547	87.190±1.547

The main effect of various conditions on the task conditions was given in Tab.8. We can couclude that the main effect on skin temperature in task state was not significant (F=2.418, p>0.05); The main effect on skin conductance difference was not significant (F=1.071, p>0.05); The main effect on EMG was significant (F=6.465, p<0.05); The main effect on ECG was not significant (F=0.171, p>0.05); The main effect on respiratory difference was significant (F=2.805, p<0.05); The main effect on the heart rate was significant (F=63.080, p<0.05).

Tab. 8: Physiological indicators data of reinforced concrete structure house under different task conditions (M±SD).

Physiological indicators	Sit	Walk	Climb stairs	Looking
Temperature (°C)	30.056±0.344	29.901±0.344	28.852±0.344	29.577±0.344
GSR (μS)	2.463±0.184	2.271±0.195	2.277±0.193	1.947±0.222
EMG (μV)	12.904±2.205	23.017±2.205	19.155±2.205	10.854±2.205
ECG (μV)	-0.245±0.046	-0.257±0.046	-0.222±0.046	-0.216±0.046
Respiration (%)	88.107±0.797	85.435±0.797	85.899±0.797	87.778±0.797
CFM (BMP)	76.641±1.786	88.667±1.786	109.027±1.786	81.951±1.786

The main effect of various conditions on the gender was given in Tab. 9. We can couclude that the main effect on the skin temperature in gender was significant (F=20.059, p<0.05); The

main effect on skin conductance difference was not significant (F=0.572, p>0.05); The main effect on EMG was not significant (F=1.196, p>0.05); The main effect on ECG was not significant (F=2.137, p>0.05); The main effect on the heart rate was significant (F=11.548, p<0.05); The main effect on the respiratory difference was significant (F=14.267, p<0.05).

Tab. 9: Physiological indicators data of reinforced concrete structure house under different gender (M±SD).

Physiological indicators	Male	Female
Temperature (°C)	28.826±0.243	30.367±0.243
GSR (μS)	2.315±0.123	2.164±0.157
EMG (μV)	17.688±1.559	15.276±1.559
ECG (μV)	-0.269±0.033	-0.201±0.033
Respiration (%)	90.598±0.563	83.011±0.563
CFM (BMP)	85.699±1.263	92.445±1.263

The interaction between weather conditions and the state of the task on skin temperature main effects was not significant difference (F=0.110, p>0.05); The main effect on skin conductance difference was not significant (F=0.607, p>0.05); The main effect on EMG was not significant (F=1.320, p>0.05); The main effect on ECG was not significant (F=0.736, p>0.05); The main effect on respiratory difference was not significant (F=0.119, p>0.05); The main effect on the heart rate was not significant (F=0.884, p>0.05).

The interaction between weather conditions and gender on skin temperature main effect was significant (F=12.842, p<0.05); The main effect on skin conductance difference was not significant (F=1.251, p>0.05); The main effect on EMG was not significant (F=2.808, p>0.05); The effect on ECG was not significant (F=1.753, p>0.05); The main effect on respiratory difference was significant (F=5.435, p<0.05); The main effect on the heart rate was significant (F=3.214, p<0.05).

Interactions of weather conditions, state of task and gender on skin temperature main effect was not significant (F=0.020, p>0.05); The main effect on skin conductance difference was not significant (F=0.205, p>0.05); The main effect on EMG was not significant (F=0.703, p>0.05); The main ECG was not significant (F=0.636, p>0.05); The main effect on respiratory difference was not significant (F=0.083, p>0.05); The main effect on the heart rate was not significant (F=0.904, p>0.05).

DISCUSSION

Under the condition of different weather, different states of task and different gender populations (Figs. 5-7), skin temperature in glulam structure environment was slightly higher than that in wood and steel concrete structure, which may be due to the influence of the indoor thermal environment on the wall insulation system of glulam structure housing, making human body feel the temperature and humidity in this environment comfortable. It is concluded that the wooden material has very good environmental regulation performance considering the related research on different materials and structure type wall within the residential indoor temperature and humidity regulation performance contrast, decorate material humidity control, wood's temperature regulation and humidity controlling performance and its influencing factors (Uang and Gatto 2003, Wang and Cho 1996, Wang and Tsai 1998, Fukumi and Tsutomu 2006). In the three structures housing environment, the temperature value of skin temperature is higher in

rainy day comparing with that in sunny state, and skin temperature with moving (walking, stair climbing) was slightly higher than that in the static state (meditation, looking at the picture). Meanwhile, female skin temperature value is higher than male's.

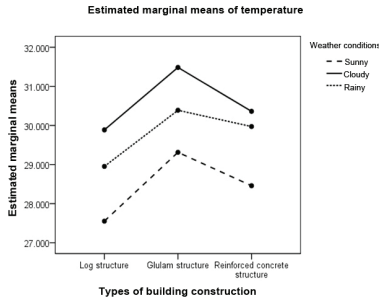

Fig. 5: The temperature changes in the three types of houses under different weather conditions.

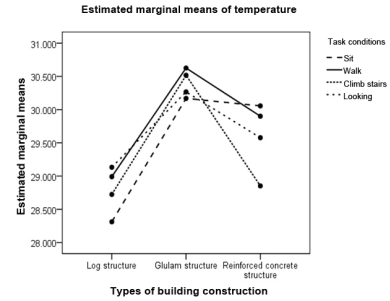

Fig. 6: The temperature changes in the three types of houses under different task conditions.

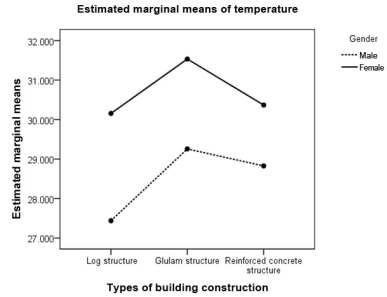

Fig. 7: The temperature changes of different gender groups in the three types of houses.

Under different weather conditions, different states of task and different gender populations (Figs. 8-10), skin conductance values (GSR) in three types of housing environment: in sunny and rainy days, skin conductance value in glulam structure and wood structure housing was higher than that of the steel concrete structure housing. The skin conductance value of the glulam structure and the wood structure housing when climbing stairs were higher than that of the reinforced concrete structure housing. The skin conductance value of male was higher than that of female, glulam structure>wood structure> reinforced concrete structure. This is due to the skin electric index was influenced by human and environmental factors at that time, walking speed and duration will not necessarily cause too big reaction. Research has shown galvanic skin response is the physiological indicators of emotional arousal (Alfons et al. 2002). In this work, emotion will be affected by additional factors when looking at the pictures and meditation. For example, when looking at the picture, galvanic skin response of people who have desire of houses was higher, and meditation thoughts and uncertain feelings may also have effect of skin conductance.

Under different weather conditions, different states of task and different gender populations (Fig. 11-13), EMG values in three types of housing environment: the EMG values of most wood structure housings > glulam structure housing > reinforced concrete structure housing. People are still more concerned the comfort of wood structure building environment, and human emotion and cognition is the guarantee of effective stimulus. The relevant scholars proved that the EMG

contributed to certain emotional states (Haag et al. 2004). In the three structure housings, EMG values in sunny and rainy were higher than that in cloudy condition, and EMG values in movement (walking, stair climbing) was higher than that of static state (sitting down, looking at the picture), and EMG values of male was higher than that of female.

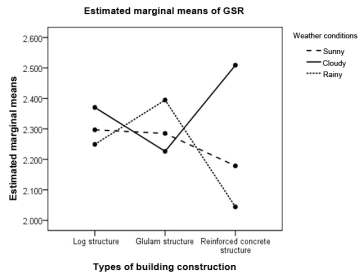

Fig. 8: The GSR changes in the three types of houses under different weather conditions.

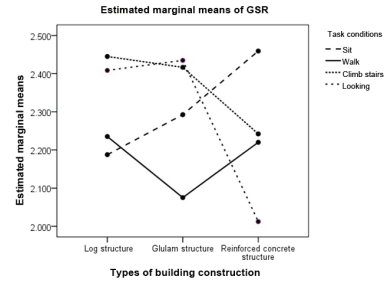

Fig. 9: The GSR changes in the three types of houses under different task conditions.

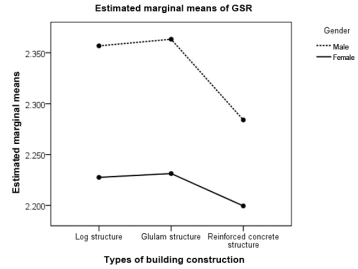

Fig. 10: The GSR changes of different gender groups in the three types of houses.

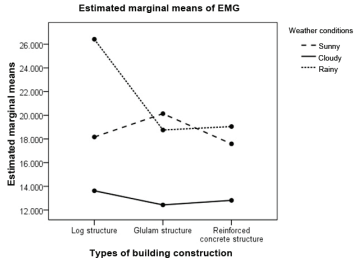

Fig. 11: The EMG changes in the three types of houses under different weather conditions.

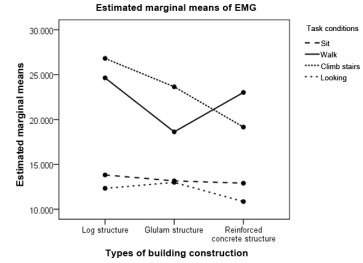

Fig. 12: The EMG changes in the three types of houses under different task conditions.

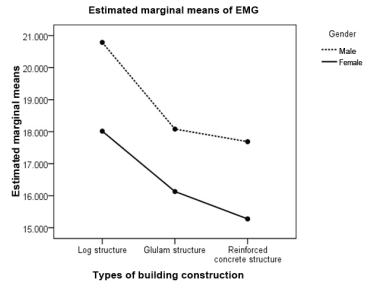

Fig. 13: The EMG changes of different gender groups in the three types of houses.

Under different weather conditions, different states of task and different gender populations (Fig. 16), ECG values in three types of housing environment: reinforced concrete structure housing ECG in most cases > glulam structure housing > wood structure housing. This may due to most people were living in the reinforced concrete structure housing, and wood and glulam structure can give people a warm and comfortable feeling. In the three structure housing, ECG values in sunny day was higher than that in cloudy condition, which may be because cloudy and rainy weather may result in the subjects be depressed, psychological anxious and emotional. Looking at pictures>climbing stairs>sitting quietly. ECG of female is higher than male.

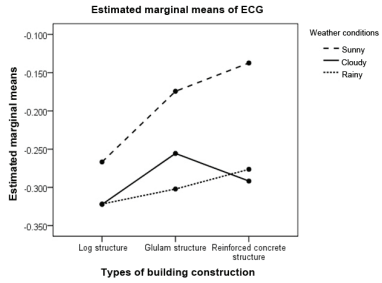

Fig. 14: The ECG changes in the three types of houses under different weather conditions.

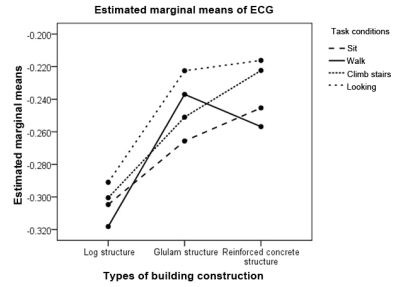

Fig. 15: The ECG changes in the three types of houses under different task conditions.

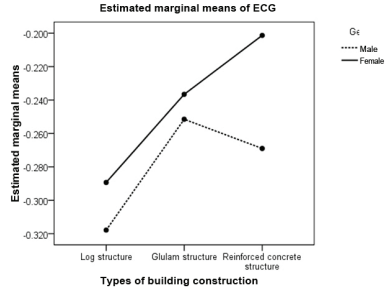

Fig. 16: The ECG changes of different gender groups in the three types of houses.

Under different weather conditions, different states of task and different gender populations (Figs. 17-19), respiration value in three types of housing environment: the respiratory frequency value in wood structure housing > glulam structure housing > reinforced concrete structure housing. Because perception is involved in the perception of how we perceive the environment and the process of cognition, people have an important effect on the cognition of the unique smell of wood. The scent of timber made room filled with cool fragrance, like a back to nature feeling, so people in the timber house environment feel relaxed. In the three structure housing, the rainy breath value is higher than that in the sunny and cloudy state, breathe value of stationary state (meditation, looking at the picture) was higher than the motion state (walking, stair climbing), male breath value is higher than female.

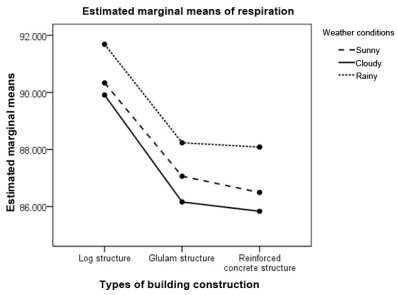

Fig. 17: The respiration changes in the three types of houses under different weather conditions.

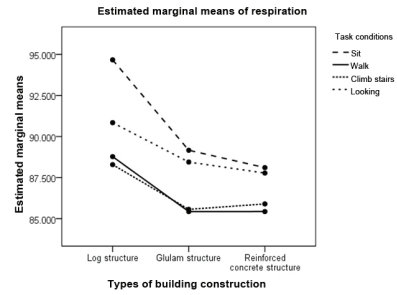

Fig. 18: The respiration changes in the three types of houses under different task conditions.

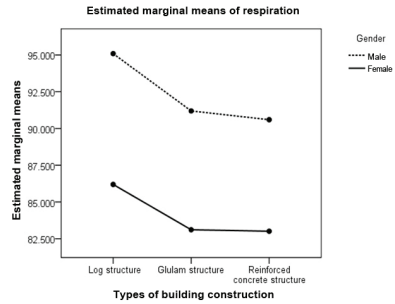

Fig. 19: The respiration changes of different gender groups in the three types of house.

Under different weather conditions, different states of task and different gender populations (Fig. 20-22), heart rate values (CFM) in three types of housing environment: Heart rate in reinforced concrete structure housing > wood structures housing > glulam structure housing . In the three structures housing environment, the heart rate value in rainy day is higher than the sunny state, heart rate in movement (walking, climbing stairs) was higher than the static state (sitting down, looking at the picture), female breath value is higher than male. The size of the heart rate is with the increase of the tasks and numerical increasing. This is because heart rate increased with the walking speed and the increase of the slope of stairs climbing (Tseng and Liu 2011). Therefore, increase in heart rate is related to the walking pace and the slope of stairs climbing.

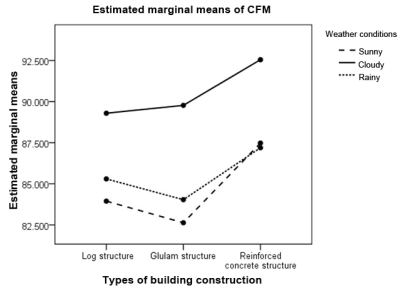

Fig. 20: The CFM changes in the three types of houses under different weather conditions.

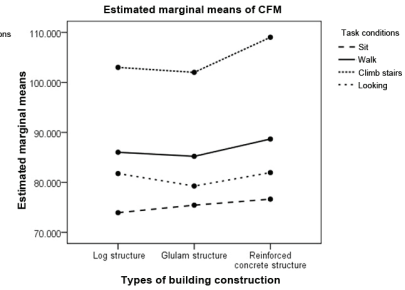

Fig. 21: The CFM changes in the three types of houses under different task conditions.

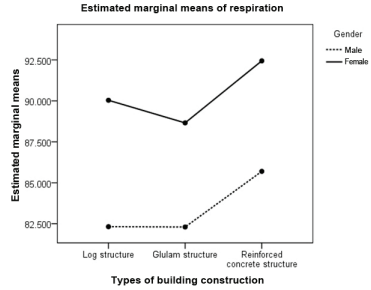

Fig. 22: The CFM changes of different gender groups in the three types of houses.

Given the above, skin temperature of participants in glulam structure building environment index is higher than that in the log and reinforced concrete structure, reinforced concrete structure ECG index is higher in comparison of that in log and glulam structure, log and glulam structure respiration index is higher than that the reinforced concrete structure. This suggests that the participants are not only interested in the log and glulam structure housing environment, but also have cheerful mood and comfortable feeling. Compared with reinforced concrete structure housing, two kinds of wooden structure houses give a person comfortable state, of which glulam structure housing was slightly better than log structure housing. Research suggests that wood materials consisting of indoor micro-environment are significantly more benefit to the human psychological, physiological, development, growth, immunity and reproduction and so on than that of metal, stone, plastic and other materials composed of the environment (Rice et al. 2006, Liu 2008). Quantitative physiological indexes monitoring can well reveal how people feel at different structure housing environment which could not be detected by some sensory instruments.

CONCLUSIONS

We investigated different types of housing environment effect on humans of psychophysiological responses under different weather conditions with CAPTIV indices. The findings were as follows:

1) Skin temperature, ECG, heart rate and respiratory rate of different types of housing environment have significant difference. Skin temperature in glued laminated environment is slightly better than that of timber and steel concrete structure. Respiratory frequency in timber and glued laminated environment is slightly higher than that of steel concrete structure, in which the highest is that in timber environment. The change trend of heart rate in three kinds of housing conditions is similar, and the heart rate of moving state is higher than that of static state.
2) The data of the structure and the physiological index of the glued laminated and timber structure are better than that of the steel concrete structure, and the physiological index of the glued laminated structure is slightly better than that of the timber structure. This clearly shows the importance of physiological measurement for evaluation of the livability of humans in different types of housing environment.
3) The building environment and interior decoration material under different weather condition caused different sensorial and physiological effects. The use of wood in building indoor environment is psychologically and physiologically beneficial.

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