Study of Emotional Changes Based on Neural Management and Electroencephalogram Experiments on Low-carbon Consumption Behavior

Qian Wang*

ABSTRACT

Nowadays, as the low-carbon environmental protection becomes the trend of the times and the living standard of consumers is constantly increasing, the influence of people's emotional changes on their low-carbon consumption is becoming more and more obvious. Therefore, it's very important to study the internal relationship between people's emotional changes and their low-carbon consumption. Based on the influence of people's emotional changes tested via EEG experiments on their low-carbon consumption, emotional self-assessment data, behavioral data, and electroencephalogram (EEG) data are analyzed. The experimental results show that under the positive induction, the score of positive emotion is obviously higher than that of negative emotion; under the positive video material induction, subjects' positive emotion declines while their negative emotion increases; under positive emotion, the low-carbon consumption accounts for 67.5% of the total consumption while under negative emotion, the low-carbon consumption only accounts for 30.12%; under positive emotion, the proportion of subjects who choose the low-carbon consumption behavior to those who choose irrational consumption behavior varies greatly, subjects are more likely to choose the low-carbon consumption behavior. The results of the study show that people's emotional changes have great influence on their low-carbon consumption behavior, which lays a foundation for in-depth researches of related contents in the future.

Key Words: EEG Experiments, Positive Emotion, Negative Emotion, Low-Carbon Consumption

DOI Number: 10.14704/nq.2018.16.2.1184 **NeuroQuantology 2018; 16(2):25-31**

Introduction

In the era of low carbon environmental protection, low carbon consumption has become a consumption trend. With the influence of human factors, consumption behavior and mode are becoming increasingly complex (Razavipour *et al*., 2015; Ciampi *et al.,* 2016; Sibilio *et al.,* 2016). A large number of survey results show that consumer behavior is mainly influenced by human factors (Masaki *et al.,* 2011; Vorobyov *et al.,* 2004), and closely related to the reason of thinking, the adaptability of behavior and the genetic genes. It is obvious that consumers' bad emotional state may result in irrational consumption behavior, which is not conducive to people's low carbon consumption (Zhao *et al.,* 2017; Khudadad *et al.,* 2013); and vice versa. In order to properly guide people's consumption behavior, the study of the relationship between emotional changes and low carbon consumption is becoming more and more important. However, it is a pity that such kind of research is rare as

Corresponding author: Qian Wang
Address: School of Management, China University of Mining and Technology, Xuzhou 221004, China
e-mail ✉ 1007486545@qq.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 17 January 2018; **Accepted:** 11 February 2018

well as qualitative mostly, lack of related experiments

In order to break this situation, this paper introduced the EEG experiment, tried to further verify this relationship through the experiment method, and then put forward the preventive countermeasures to consumer's low-carbon consumption behavior under negative emotion.

In fact, the most representative event-related potential technique in cognitive neuroscience research has been referred to as the "inspection window for advanced brain function" (Van *et al.,* 2016), which records the brain evoked potential on the surface of the skull to reflect the electrophysiological changes of the brain during cognitive process.

At present, this innovative technology has been widely used in many fields such as cognitive neurology, medicine and marketing, and has proven its unique superiority. In fact, China has been studying emotions since ancient times. The emotions were divided into "like, dislike, pleasure, anger, sorrow and joy" in ancient times, and have continued to this day. In addition, many scholars at home and abroad use pictures, videos and other methods, and conduct emotional stimulation of different groups so as to verify the fact that different situations can induce different emotions. In the course of the experiment, we collected the EEG signals, analyzed the relationship between emotion and the neural mechanism of the brain, and obtained a series of research results (*et al.,* 2010; Shen *et al.,* 2016).

Methods

Experimental Design

Emotional induction

Emotion has specific physiological patterns and corresponding expressions, while the emotional dimension theory thinks that human emotion changes gradually instead of isolated existence or a simple mixture of several emotions (Mi *et al.,* 2011). The emotional dimension theory generally consists of two dimensions: pleasantness (transition from depression to excitement) and excitement (transition from unhappiness to pleasure). As shown in the Emotional dimension model of Figure 1, emotion falls into positive emotion and negative emotion and the emotional dimension model may better interpret the differences in emotional level and the process of emotional transformation.

According to Figure 1, positive emotion includes joy, happiness, satisfaction, interestingness and funniness while negative emotion includes anxiety, fear, anger, disgust, and sadness. The trigger for this experiment was video, which was played to the subjects to ensure that the subjects' emotions may be maintained for a longer time. A section of *Lost in Thailand* was selected as the positive emotion trigger while a section of Dearest as the negative emotion trigger.

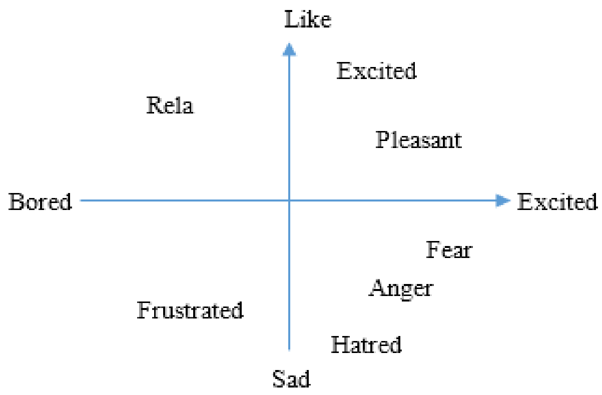

Figure 1. Emotional dimension model

Experimental indexes and objects

This experiment used two kinds of emotion induction: positive emotion and negative emotion, and low-carbon consumption behavior and irrational consumption behavior mixed design. It adopts E-Prime2.0 programming, automatically storing parameters such as subject selection, feedback results and reaction time. The experiment process falls into four parts, each of which includes 30 experiments, totally 120 experiments. In order to eliminate emotional fatigue and visual fatigue, the interval between each part is 10 minutes.

Behavioral data indicators and EEG data indicators were used as the indicators of this experiment. Behavioral data indicators were measured according to consumption behavior written by E-Prime software, and EEG data were measured according to the peak latency and amplitude of EEG data waveform. Test equipment of EEG experiment uses Neurone EEG/ERP related potential system, which consists of EEG amplifier (Neurone Model Black amplifier, as shown in Figure 2) and brain electrode cap (Ag/AgCl64 lead Neurone electrode cap, as shown in Figure 3), with the sampling frequency 500Hz. The reference electrode at 10mm above the eye was used to measure the vertical eye electrical signal, and the reference electrode at the outside 5mm of the eye recorded the horizontal eye electrical signal. All the electrodes were recorded with the left and right papillomastoid electrodes as the reference electrodes. In order to ensure the quality and signal-to-noise ratio of the collected data in the whole experiment, the impedance of all the electrodes should be reduced to below 10k.

Figure 2. Neurone Model Black amplifier

Figure 3. Ag/AgCl lead Neurone electrode cap

Experimental Process and Data Analysis

Experimental process

The main equipment of the experiment includes amplifier, stimulation system, analysis system and electrode cap. Before the experiment, the EEG signal is debugged to confirm that the equipment is in good condition. The experiments should be carried out in the dark and closed environment without external interference to reduce electromagnetic interference from the external environment. The subjects were women and healthy, without a history of mental illness, and voluntary to participate in the experiment. They should wear electrode caps to ensure the impedance of the electrode point is less than 10k Omega. Figure 4 shows the well-connected electrode lead diagram, where the blue electrode is a dynamic monitoring point, the green electrode indicates the impedance of less than 5kΩ, while the red electrode which once appears indicates the impedance of more than 10kΩ, in which it's necessary to wait for the impedance of less than 10kΩ, or supplement conductive paste in electrode point.

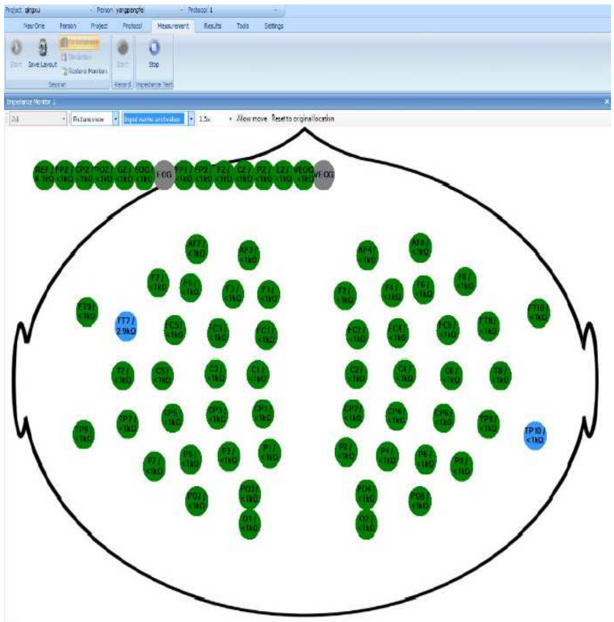

Figure 4. Well-connected electrode lead diagram

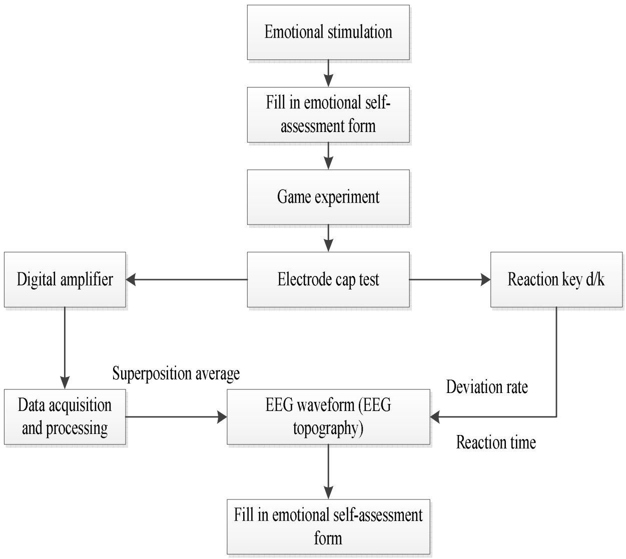

Figure 5. ERP test flow chart

The detailed experiment flow is shown in Figure 5. Through the video emotion stimulation, the subjects needs to fill in the emotion self-rating scale, during which the electrode cap will read the brainwave changes of the subjects and magnify it by the amplifier, drawing the EEG or EEG topography. The subjects need to re-fill the emotion self-rating scale. The acquisition of behavioral data and EEG data are carried out synchronously, and through the electrode cap and the electro-ophthalmic electrode, the EEG of subjects can be recorded in full cycle, in order to associate signal time with behavioral data of the subjects. Write a tagline in the E-Prime program and mark the selected d/k moments to facilitate the later data processing.

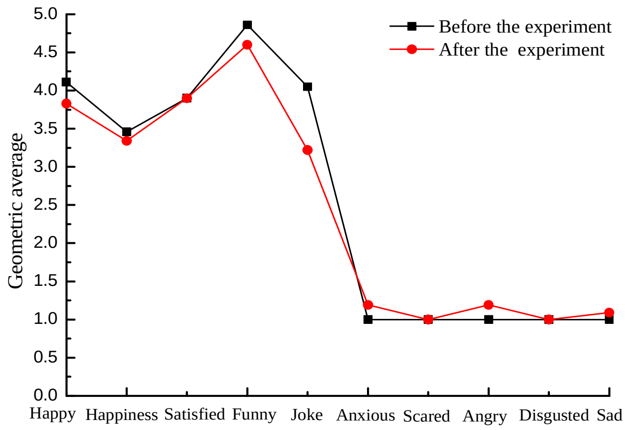

Figure 6. Positive emotional mean contrast comparison

Figure 7. Positive emotions total score contrast

Experimental data analysis

The data of this experiment included emotional self-evaluation data, behavioral data and EEG data. The emotion self-evaluation data was carried out by questionnaire to obtain the self-evaluation table before and after the positive and negative emotion experiment, with totally four copies of data for respectively calculating the scores of each emotion before and after the experiment, that's, the total score and geometrical mean, the latter of which is less influenced by extreme values, so the score level of positive and negative emotions in different cases is more accurate than total score with geometrical mean as measurement standard. Figure 6 and 7 show the curves of the total score and geometrical mean before and after the experiment of positive emotions composed of pleasure, happiness, satisfaction, interest and laughter, respectively under the condition of positive video material. It can be seen that in the positive video material induction, the positive emotion of subjects declines while their negative emotions increases. Negative emotion is affected by positive emotion and the negative emotion increases slowly with time. Furthermore, the two diagrams show that the score of positive emotion is significantly higher than that of negative emotion under positive induction. Figure 8 and 9 the curves of the total score and geometrical mean before and after the experiment of negative emotions composed of worry, fear, disgust and sadness, respectively under the condition of negative video material. Under the induction of negative video materials, negative emotions decreased and negative emotion was significantly higher than positive one.

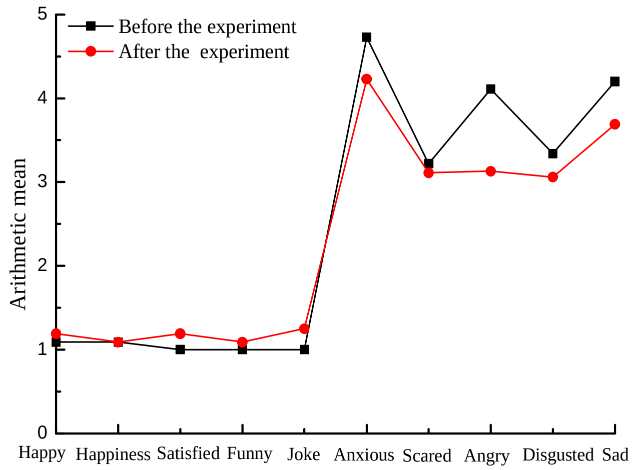

Figure 8. Negative emotional mean contrast comparison

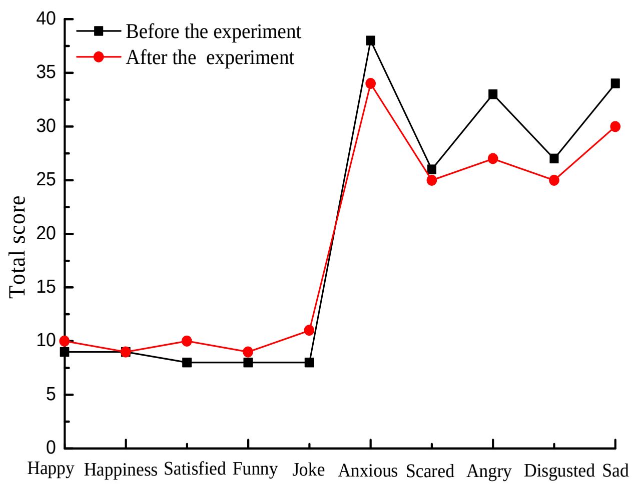

Figure 9. Negative emotions total score contrast

Table 1. Sample statistics of the proportion of different behavior under the same emotion

Type	Behavior	Mean	N	standard value	Standard error of mean value
Positive emotion	Low-CC	67.75%	80	0.12691	0.4487
	Irrational-C	31.50%	80	0.12247	0.4330
Negative emotion	Low-CC	30.12%	80	0.15085	0.5333
	Irrational-C	70.25%	80	0.15248	0.5391

Note: Low-CC: Low carbon consumption; Irrational-C: Irrational consumption

Table 2. Sample Correlation Coefficient of Different Behaviors under the Same Emotion

Type	Behavior ratio	N	Correlation coefficient	Sig.
Positive emotion	Low-CC: Irrational-C	80	-0.973	0.000
Negative emotion	Low-CC: Irrational-C	80	-0.999	0.000

Table 1 shows the proportion of low-carbon consumption and non-ideal consumption under the same emotion. It can be seen that under positive emotion, the proportion of low-carbon consumption is 67.5% and non-rational consumption is 31.5%. Under negative emotion, low-carbon consumption accounted for only 30.12%. Table 2 shows the correlation coefficients of two behavioral ratios under the same emotion. Under positive emotional conditions, the correlation coefficient between low-carbon consumption and non-rational consumption is -0.972 and the Sig. value is less than 0.05, which indicates that low-carbon consumption ratio is negatively related to non-rational consumption, with significant correlation. In paired difference test, Sig. is less than 0.05, which indicates significant difference, that's, under the positive emotion, there is a significant difference between low-carbon consumption behavior and non-rational consumption behavior and subjects were more likely to choose low-carbon consumption behavior. Under negative emotion, the correlation coefficient between low-carbon consumption and non-rational consumption is -0.999 and the Sig. value is less than 0.05, which indicates that low-carbon consumption ratio is negatively related to non-rational consumption, and subjects are more likely to choose irrational consumption behavior. After filtering, removal of eye electricity, EEG segmented processing of EEG data, Table 3 and 4 show AF8 point peak and latency data with positive and negative emotion of subjects. Under positive emotion, the amplitude mean of subjects' low-carbon consumption behavior is 6.43uV, the amplitude mean of subjects' irrational consumption behavior is 4.97uV, the latency mean of subjects' low-carbon consumption behavior is 244ms and the latency mean of subjects' irrational consumption behavior is 223ms. Under negative emotion, the amplitude mean of subjects' low-carbon consumption behavior is 6.46uV, the amplitude mean of subjects' irrational consumption behavior is 7.78uV, the latency mean of subjects' low-carbon consumption behavior is 440ms and the latency mean value of subjects' irrational consumption behavior is 418ms.

Table 3. Positive emotion test AF8 peak and latency data

Behavior No.	Low-carbon consumer behavior		Irrational consumer behavior	
	Amplitude/ uV	Latency data/ms	Amplitude/ uV	Latency data/ms
PE1	7.55	211.7	5.55	209.7
PE2	6.70	263.7	4.52	210.7
PE3	5.93	294.1	4.82	228.7
PE4	5.79	228.7	4.63	224.8
PE5	6.09	268.0	4.79	212.4
PE6	6.39	212.6	5.11	214.6
PE7	6.18	244.5	4.91	262.5
PE8	6.70	224.5	5.33	215.8

Table 4. Negative emotion test AF8 point peak and latency data

Behavior No.	Low-carbon consumer behavior		Irrational consumer behavior	
	Amplitude/ uV	Latency data/ ms	Amplitude/ uV	Latency data/ms
PE1	9.35	386.0	8.25	398.4
PE2	8.38	453.3	6.12	415.1
PE3	6.79	363.0	5.62	453.5
PE4	5.88	421.7	4.71	435.5
PE5	8.42	412.1	7.32	462.2
PE6	7.61	492.4	6.54	512.2
PE7	7.61	398.3	6.33	413.4
PE8	8.15	416.1	6.72	423.4

Analysis on the Influence of Emotion on Low-carbon Consumption Behavior

Influence of emotion on the decision-making of low-carbon consumption behavior

Under positive emotion, 67.5% subjects choose low-carbon consumption behavior while under negative emotion, 30.12% subjects choose low-carbon consumption behavior, with Sig. is less than 0.05 in the paired difference test of proportions of low-carbon consumption behavior under different emotions, which shows a significant difference. The low-carbon consumption behavior under positive emotion is 37.38% greater than that under negative emotion, that's, subjects significantly are more likely to choose low-carbon consumption behavior under the positive emotion. As is known from EEG data, there is no significant difference in the total response time of subjects under two emotions.

Figure 10 shows the emotion-based low-carbon consumption behavior pattern, which is proposed in combination with people's physiological and psychological behavior. Under the positive emotion, people have normal thinking status so it's not proper to make rational behavior. But in reality, they may have negative emotion, in which the amplitude will increase; peak latency is longer than in normal status, and executive function in the frontal region of the brain decreases, suppressing people's normal criticism and flexibility and resulting in the irrational consumption behavior.

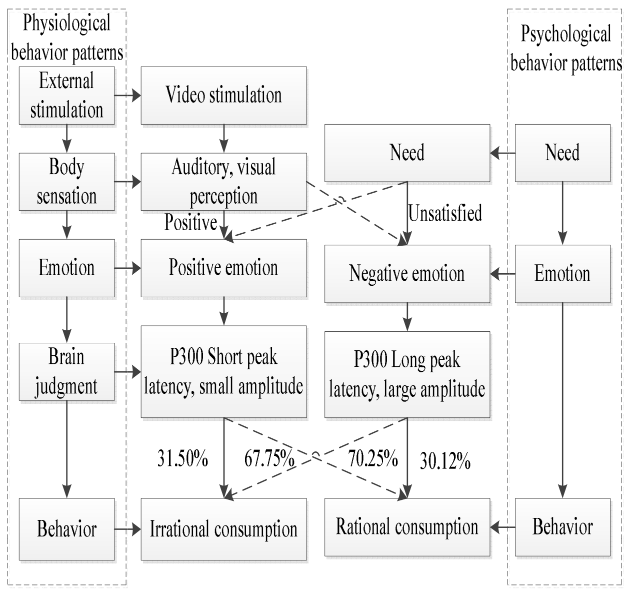

Figure 10. Emotional low-carbon consumption behavior patterns

Prevention of low-carbon consumption behavior based on negative emotional control

According to the above analysis, negative emotion can be controlled to reduce irrational consumption, and the main factors affecting emotion include family condition, physical condition, salary, working environment and so on (Quigley *et al.,* 2014; Chen *et al.,* 2016; Danko *et al.,* 2011). In view of these influencing factors, the control strategies of negative emotion are given below. First: keep healthy, with healthy habit and lifestyle, which have an important impact on the state of life, and health will bring a happy mood. Second: enjoy life, learn to enjoy life, don't waste time on unnecessary anxiety, don't be too critical to real life, and often have a grateful heart. Third: learn to relax, arrange the living space reasonably, always arrange a holiday for yourself, and maintain the feeling of refreshing. Fourth: entertainment often goes to watch some comedies, search for some interesting news and jokes, and share them with the people around. In any case, you should be calm and think rationally, and your behavior should not be influenced by your emotions.

Conclusion

In this paper, we need to analyze the effects of emotional self-assessment data, behavioral data and EEG data of subjects on low-carbon consumption behavior based on EEG experiments, with the specific conclusions as follows:

(1) Neurone EEG/ERP related potential system was used in the test equipment of EEG. The system is composed of EEG amplifier and EEG electrode cap, and the sampling frequency is 500Hz. The EEG data are measured by the peak latency and amplitude of the EEG data in the experimental process.

(2) Under the induction of positive video materials, the positive emotion of the subjects declines while their negative emotion increases. Negative emotion is affected by positive emotion and the negative emotion increases slowly with time. It's opposite in the case of the induction of negative video materials.

(3) Under positive emotion, there is a significant difference in the proportion of low-carbon consumption behavior and irrational consumption behavior of the subjects, who are more likely to choose low-carbon consumption behavior.

(4) Under the negative emotion, the amplitude in positive emotion will increase; peak latency is longer than in normal status, and executive function in the frontal region of the brain decreases, suppressing people's normal criticism and flexibility and resulting in the irrational consumption behavior.

References

Cao H, Li Y. The Research of Knowledge Workers' Competencies Based on EEG Experiment of Mental Operations. iBusiness 2010;2(01):51-56.

Chen X, Han L, Pan Z, Luo Y, Wang P. Influence of attention on bimodal integration during emotional change decoding: ERP evidence. International Journal of Psychophysiology 2016;106:14-20.

Ciampi G, Rosato A, Sibilio S. Dynamic simulation of a micro-trigeneration system serving an Italian multi-family house: energy, environmental and economic analyses. International Journal of Heat and Technology 2016;34:S295-302.

eISSN 1303-5150

Danko SG, Gracheva LV, Boytsova YA, Solovjeva ML. Induction of emotional states by reading aloud texts with various emotional valences and changes in the eeg power in the β and γ frequency bands. Human Physiology 2011; 37(5): 555-58.

Khudadad N, Ali B, Jan K. Measuring the impact of low carbon technologies and products on domestic fuel consumption. Renewable Energy 2013; 49(1): 115-18.

Masaki H, Ohira M, Uwano H, Matsumoto K. A Quantitative Evaluation on the Software Use Experience with Electroencephalogram. International Conference 2011; 6770(4): 469-77.

Mi L, Nie R, Li H, Li X. Empirical research of social norms affecting urban residents low carbon energy consumption behavior. Energy Procedia 2011; 5(1): 229-34.

Quigley KS, Barrett LF. Is there consistency and specificity of autonomic changes during emotional episodes? Guidance from the conceptual act theory and psychophysiology. Biological Psychology 2014; 98(1): 82-94.

Razavipour F, Sameni R. A study of event related potential frequency domain coherency using multichannel electroencephalogram subspace analysis. Journal of Neuroscience Methods 2015; 249: 22-28.

Shen L, Sun Y. Review on carbon emissions, energy consumption and low-carbon economy in china from a perspective of global climate change. Journal of Geographical Sciences 2016; 26(7): 855-70.

Sibilio S, Ciampi G, Rosato A, Entchev E, Yaici W. Parametric analysis of a solar heating and cooling system for an Italian multi-family house. International Journal of Heat and Technology 2016; 34(S2): S458-64.

Van LR, Houlihan SD, Pal P, Sacchet MD, Mcfarlaneblake C, Patel PR. Source-space eeg neurofeedback links subjective experience with brain activity during effortless awareness meditation. Neuroimage 2016; 151: 117-27.

Vorobyov V, Pesić V, Janać B, Prolić Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects baseline and scopolamine-modified electroencephalograms in freely moving rats. International Journal of Radiation Biology 2004; 80(9): 691-98.

Zhao G, Guerrero JM, Jiang K, Chen S. Energy modelling towards low carbon development of Beijing in 2030. Energy 2017;121:107-13.