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COGNITIVE PROCESSING TOWARD TRADITIONAL AND NEW CHINESE STYLE FURNITURE: EVIDENCE FROM EYE-TRACKING TECHNOLOGY

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ABSTRACT

Eye-tracking technology was shown to have the ability to indicate human's cognitive preferences toward objects. Using eye-tracking technology to study the cognitive preferences on different Chinese furniture style may have the potential to promote the furniture design from a novel perspective. Experiment was designed to test the differences of eye movement index (total fixation time, average fixation counts and average pupil diameter) within variables of gender, major and furniture styles. Participants were asked to observe two sets of different styles of Chinese furniture pictures on computer screen. Significant differences of total fixation time and average fixation counts were found between different furniture styles ($p<0.01$), gender ($p<0.001$), but not in major ($p>0.05$). Significant difference was also found in average pupil diameter in different furniture styles ($p<0.01$) and gender ($p<0.01$).Subjects' fixation time stayed longer on new Chinese style furniture pictures than traditional furniture pictures. The results indicated that compared to traditional Chinese style furniture, people tend to take more interest in the new Chinese style furniture. Gender as a factor had a significant influence on the cognitive processing towards the viewing of pictures of the Chinese style furniture. Meanwhile, subjects paid more attention to the decorative details on the furniture, implying appropriate design and decoration may improve people's interest to the furniture.

KEYWORDS: Cognitive processing, eye-tracking technology, traditional furniture. new chinese style furniture, furniture design.

INTRODUCTION

With the development of science, technology and economy in China today, Chinese culture is becoming more and more popular all over the world. As one of the representatives of the Chinese design culture, Chinese furniture have earned an international high praise due to its excellent technical details and unique modelling. However, along with developing of modern design of furniture, the modelling and scale of traditional Chinese furniture could not meet the needs of modern consumers any more. Recent years a new Chinese style furniture appeared, which evolved from the traditional style Chinese furniture, have becoming more and more popular in the market today. As a product, furniture's style can affect user preference and plays an important role in consumer's purchasing decisions (Guo et al. 2016). The product appearance style plays an important role in consumers' preference and purchase (Chuang et al. 2001, Lin et al. 2007). Different style of furniture can make differences in people's visual perception and their aesthetic preference, which are all important factors for consumers' purchasing decision.

Many factors should be considered when designing furniture or products, such as consumer preferences (Hong et al. 2008), color (Hsiao et al. 2008), texture (Chang 2008), and interfaces (Artacho-Ramirez et al. 2008). Studying people's cognition towards these factors is beneficial to the design of furniture that could meet people's needs (Hsiao et al. 2010). As both the traditional and new Chinese style furniture were mainly made by wood, it attracts consumer by its natural color, gloss, and the unique texture. Studying the wood products using in interior decoration and furniture can also reveal the cognitive preference of consumers which is important for designers to understand their needs.

Because users' cognitive preference contains potential and intuitive feeling, the evaluation of it is usually difficult. Researchers have tried many methods to make this subjective evaluation objective. Traditionally, emotional questionnaire (Agost and Vergara 2014), fuzzy decision support system (Alptekin 2012, Hsiao and Ko 2013) and Kano's model in Kansei engineering (Llinares and Page 2011) have been used for users' cognitive preference measurement. However, these methods were still based on consumers' subjective description but ignoring their affective and intuitional responses (Ariely and Berns 2010, Calvert and Brammer 2012, Ding et al. 2016).

The eye-tracking study can reflect user's cognitive process in an objective way (Nahapiet et al. 1998). Using eye-tracking technology, we can record user's data of eye movement and then analysis their psychological process of cognitive activities (Martin et al. 2011). Researchers have used eye movement as an effective tool to reveal human's cognitive process, covert perceptual aesthetic evaluation of artworks and aesthetic qualities more objectively (Pham 1999, Chuang et al. 2001, Nodine and Krupinski 2003, Cawthon and Moere 2007, Yadav et al. 2013). Subjects' aesthetic preference could be quantified and predicted even the eye behavior was the only physiological parameter being monitored (Khalighy et al. 2015). Recent study on eye tracking technology provides a method to identify in what order and for how long when subjects focus on particular areas of an image (Maier et al. 2009). As viewers collect information from things such as paintings, their eyes rapidly jump or saccade followed by pauses or fixations (Locher 2006). With the help of eye tracker, we could record people's eye movement while they were receiving visual information in real-time and obtain data of the cognitive processing (Jacob et al. 2003). As a result, subject's visual evaluation process can be analyzed and explained psychologically and

spiritually. Using eye tracking technology when analyzing consumers' psychological activity, subject's aesthetic preference, visual cognitive processes and emotion, etc. can be objectively studied through the eye movement indexes such as the fixation point and the pupil diameter.

The majority of the eye movement research about visual cognition had been focused on reading, package labels, traditional printed materials, psychology and other related fields (Rayner 1998, Leven 1991, Jakob2006, Rayneret al. 2004). Some researchers started to use eye-tracking technology to analyze people's preference in different field (Zhang et al. 2013, Houtkamp and Toet 2012, Shong et al. 2016). However, studies about the wood furniture style and its cognitive preference are still far from systematic. There has been a lack of study about comparing the new style Chinese furniture and the traditional one. Overall, many aspects in the academic field of furniture style recognizing are worth exploring and need to be improved. Comparing with other methods, using eye-tracking technology to evaluate people's aesthetic cognition of furniture can provide a clearer and more objective evaluation. The successful applications of eye tracking in the field of design and psychologic research indicate that combining eye tracking technology with the aesthetic evaluation of furniture may bring innovative ways to designing, which further to develop and design wood furniture products that can meet consumers' true needs.

Since either the study was based on interview method or questionnaire method, researchers in previous studies have always been ignoring people's potential motives, desires, values and attitudes, studies which investigated people's cognitive preferences could hardly reveal people's real thoughts and attitudes (Wilson et al. 1995). As a result, exploring people's real needs, experience and their internal cognitive processing mechanism has great significance (Dirican and Göktürk 2011). As eye movements reflect people's implicit cognition, this single measurement plays an important role which focus on people's cognitive and decision-making process (Kahneman 2002). By using the eye movement technology, this study attempts to investigate people's cognitive preference of the new style Chinese furniture and the traditional Chinese furniture from different subject backgrounds.

MATERIAL AND METHODS

Participants

Twenty-eight healthy right-handed students (seven males from major in design, 7 from other major, 7 females from major in design and 7 females are not with mean age of 22.4, SD=2.998, range 18-27 years) from Beijing Forestry University were recruited as participants. No color blindness (including local and full color blindness), anomalous trichromatism or night blindness was found in all participants. All participants signed written consent forms to participate before the experiment and received a gift worth about 4 $ as compensation.

Apparatus

The experiment was conducted in a quiet and soft light lab in College of Material Science and Technology, Beijing Forestry University. The eye tacker was Ergo LAB man-machine environment synchronization platform of eye movement module Tobii x2-60. This instrument supports computer composition optical recording pupil and corneal reflection principle (Fig. 1). Participants watched the stimuli on a 19-inch liquid crystal display (resolution 1024 x 768 pixels, 60Hz), and the process was controlled by an eye movement software in the computer.

Fig. 1: Eye tracker Tobii X2-60.

Stimuli

The stimuli were selected from websites, consisting of 24 traditional and new Chinese style furniture pictures (12 traditional style and 12 new). These pictures were divided into 12 groups, each group included a traditional furniture picture on the left and a new Chinese style furniture picture on the right. Both furniture are the same kind of furniture (Fig. 2). The stimuli were processed by Photoshop CC to make sure that all the pictures have similar tones and with white background.

Fig. 2: Examples of the stimuli ("2a"– Traditional Chinese style furniture and "2b" – New Chinese style furniture).

Eye-tracking measures

Before the experiment, the areas of interest (AOIs) were defined as follow: the "left furniture" and "right furniture". For each AOI, two measures were calculated using Tobii x2-60: fixation time (a sign of regional importance. The more important the area is, the more the fixation time is), average fixation counts (related to aesthetic preference analysis). For each group, one measure was calculated: pupil diameter (pupil size is measured to reflect pupil diameter).

Procedure

Subject was first asked to sit in front of a computer screen with a distance of 80 centimeters. Device recognition adjustment (of the focus of eyesight) was then performed. Before the test started, subject was told to read the instruction of the test procedure. After subject had understood the testing requirements and procedures, the computer screen starts to play the stimuli. Before each stimuli appeared on the computer screen there was a blank page showed, which has a "+" symbol located at its center. The blank page was showed at first and remained for 200 ms. After that, the test image (the furniture picture) appeared and remained for 6000 ms of time. The subject could skip the picture if he/she watched shorter than the default time by pressing the space bar on keyboard. The eye movement data was automatically collected by eye tracking device during the test. The order of the image of 12 New Chinese Style and 12 Traditional Chinese Style was randomized so that each subject watched the picture with a different order. And Fig. 3 gives the whole process.

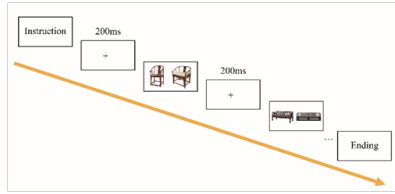

Fig. 3: The process of the test.

Data processing and statistical methods

The fixation time was excluded if lasted longer than 1500 ms or shorter than 50ms. This was because the fixation time shorter than 50 ms were usually contained not enough valid information and the fixation time longer than 1500 ms were generally generated by machine or man-made factors (Over et al. 2007). There were three independent variables in this experiment, each variable has two categorical types. The first variable was "furniture style" and the subsets were "New Chinese Style" and "Traditional Chinese Style". The second variable was "Gender" and the subsets were "male" and "female". The third variable was "Major" and the subsets were "professional" and "non-professional". The primary objective of the analysis was to test the differences of eye movement index (total fixation time, average fixation counts and average pupil diameter) within each independent variables of gender, major and furniture styles. The following procedure of statistical methods was used:

1) Kolmogorov-Smirnov and Shapiro-Wilk test for first time testing of normality;
2) Natural Logarithm transformation if data was non-parametric (Inal et al. 2010);
3) Second time testing of normality;
4) Since all eye-movement data (raw data and log transformed) violated the assumptions of parametric test, non-parametric tests were used to analyze the raw datasets. Paired-Samples Wilcoxon Signed Rank Test was used to test the difference of dependent variable between groups within dependent variables and Independent Samples Mann-Whitney U Test was used to test the difference of dependent variable between groups within each independent variable.

According to the dependent variable, experiment data were divided into 3 groups to analyze separately. Each group were then sorted based on subject's gender, major and furniture styles of the test picture showed. Descriptive characteristics of study participants are summarized as mean values ± standard deviation (SD). Significance was set at $P < 0.05$. All statistical analyses were performed using Microsoft Excel 2016 and SPSS 21.0 (SPSS, Chicago, IL).

RESULT AND DISCUSSION

Total fixation time

The total fixation time collected during the viewing of the furniture pictures were analyzed using non-parametric tests. Paired-Samples Wilcoxon Signed Rank Test indicated there is a significant difference of total fixation time between the Traditional and New Traditional furniture style pictures ($p<0.01$), total fixation time in the New Traditional is significantly higher than the Traditional style group (mean difference=0.1 ms, $z=2.98$). Independent Samples Mann-Whitney U test showed that there is a significant difference of total fixation time across gender groups ($p<0.001$). Female participants had significantly higher total fixation time than male participants (mean difference=0.58 ms, $z=4.43$). No statistical significance was found in

total fixation time between participants in different profession group (mean difference=0.42 ms, p=0.96). Data showed in Tab. 1 and Fig. 4.

Tab. 1: Summary of the results of total fixation time evoked by the stimuli.

Variable	Total fixation time (s)		p
	Mean (SD)	Mean (SD)	
Gender	Male	Female	
	2.14(1.60)	2.72(1.50)	<0.001
Furniture style	Traditional	New Traditional	
	2.44(1.57)	2.54(1.54)	0.003
Major	Professional	Non-professional	
	2.23(1.44)	2.65(1.67)	0.96

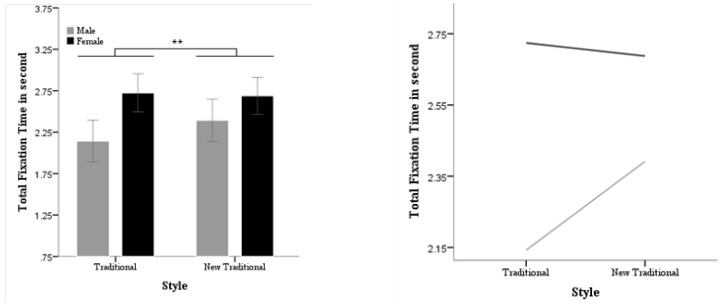

Fig. 4: Comparison of total fixation time between variables.

Average fixation counts

The average fixation counts within each variable were tested using non-parametric tests. Paired-Samples Wilcoxon Signed Rank Test indicated there is a significant difference of average fixation counts between the Traditional and New Traditional furniture style groups (p<0.001), average fixation counts in the New Traditional is significantly higher than the Traditional style group (mean difference=0.83, z=14.30). Significant difference was found between male and female groups, with mean difference of 2.78 (p<0.01, z=4.49). Although non-professional participants had more average fixation counts than profession participants, no significant difference was found across different profession groups (p=0.304). Data showed in Tab. 2 and Fig. 5.

Tab. 2: Summary of the results of average fixation counts evoked by the stimuli.

Variable	Average fixation counts (n)		p
	Mean (SD)	Mean (SD)	
Gender	Male	Female	
	10.15(5.91)	12.93(6.06)	<0.001
Furniture style	Traditional	New Traditional	
	11.57(6.13)	12.40(6.34)	<0.001
Major	Professional	Non-professional	
	11.05(5.92)	12.08(6.31)	0.304

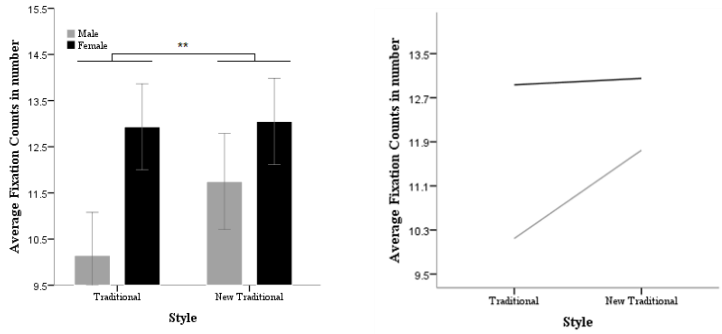

Fig. 5: Comparison of average fixation counts between variables.

Average pupil diameter

The average pupil diameter within the variable of gender and profession are tested using non-parametric test of Independent Samples Mann-Whitney U test. Significant differences are found in both variables. For gender, average pupil diameter between male and female groups has a mean difference of 0.17 mm ($p<0.001$, $z=-3.31$), male group has higher average pupil diameter than female group. Significant difference is found ($p<0.001$, $z=-9.228$) across different major groups. Participants from professional group had higher average pupil diameter than non-professional group (mean difference=0.44). Due to technical reasons, average pupil diameter across different furniture groups was not measured. Data showed in Tab. 3 and Fig. 6.

Tab. 3: Summary of the results of average pupil diameter evoked by the stimuli.

Variable	Average pupil diameter(mm)		p
Gender	Mean (SD)	Mean (SD)	
	Male	Female	
Major	3.33(0.47)	3.16(0.37)	<0.001
	Professional	Non-professional	
	3.47(0.42)	3.03(0.32)	<0.001

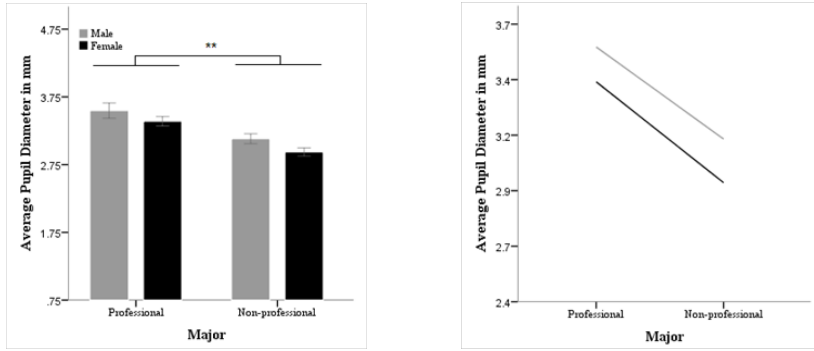

Fig. 6: Comparison of average pupil diameter between variables.

Moving sequence of the image's fixation point

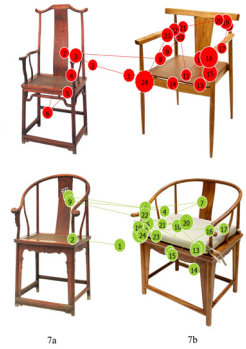

Fig. 7: Analysis of moving sequence of gaze point ("7a"– Traditional Chinese style furniture and "7b" – New Chinese style furniture).

Before each picture appears, the center of the screen stayed for one "+" for about a second, so the first point of view was usually located in the middle of the screen. From Fig. 7 you can find the participants usually observed from left to right, and the gaze points stayed on the new Chinese style furniture pictures are more than the traditional furniture pictures. In addition, the gaze points always stay at the furniture parts with more non-geometric modeling and decorative element.

The influence of furniture style on cognitive processing

Results showed that the total fixation time of new Chinese style furniture is significantly longer than that of traditional Chinese style furniture. Researchers believed that the feeling of freshness led to more fixation time to the interest part of a picture (Brockmale and Henderson 2005). Compare to traditional Chinese style furniture, new Chinese style furniture possess more modern elements on their modeling design, which caused participants to have better fresh feelings during the test. That may explain the fact that participants took longer fixation time to observe the new Chinese style furniture. The average fixation counts in the new Chinese style furniture is also significantly higher than that of traditional Chinese furniture. The index of fixation counts have been used to analyze people's visual system (Siva et al. 2013) and proved to have positive correlations with human evaluation (Doherty 2010). Thus we could deduce that compare to the traditional Chinese style furniture people tend to have a much more positive appraisal on the new Chinese style furniture.

As both the new and traditional Chinese furniture often made by wood materials, the biggest difference between them is their modeling and decoration. The modeling of the traditional Chinese furniture trend to have more curved and carved components than that of the new Chinese style furniture. However, for today's younger generation, products with concise and simple outer appearance are becoming more popular in their daily life. That could be a reason of that young people tend to pay more attention on the new Chinese style furniture during the experiment.

The influence of major and gender on cognitive processing

Form the results above, the total fixation time and average fixation counts of female is more than that of male. This indicated that people with different gender have different eye movement patterns in the process of visual cognition (Andersen et al. 2012). This phenomenon may due to the fact that compared with males, females tend to be more careful and patient when observing objects. Females tend to take longer time and focus in details in the process of visual cognition. The results showed that the total fixation time and average fixation counts have not differed significantly between participants with different major. Both new and traditional Chinese style furniture we had chosen as stimuli in the experiment are both common furniture styles in the market, and both the participants with major background of design and non-design were familiar with the style of the furniture. That implied the differences in major did not cause divergence of interest on Chinese style furniture during test.

On the other hand, female participants had smaller average pupil diameter than that of male and those from non-design major had smaller average pupil diameter than those from major of design. Many studies have found reliable links between cognitive processing and changes in pupil diameter (Nakayama et al. 2002, Iqbal et al. 2005). Further studies showed that the average pupil diameter of people in happy and positive emotion is bigger that in clam mood (Blackburn and Schirillo 2012) and the average pupil diameter of people in negative emotion caused by pain and sadness is smaller than that in clam mood (Bradshaw et al. 2011, Bradshaw et al. 2012). Compared with male, female at the same age always matured earlier and were calmer during the test, perhaps can explain the differences of pupil diameter in this study. Other studies showed that different professional training causes different brain development of people (Fan and Wang 2011). For participants with background of design, they were trained to express their emotion during daily work, so compare to the other group, they may have been better emotionally stimulated during the test. This could be a possible explanation of the differences between the people from different major.

The influence of Region of Interest (ROI) in different furniture style on cognitive processing

From the image analysis the results show that the people's fixation points on the furniture are usually focus on the details, often pay more attention to the decorative part of the furniture. On the other hand, there is significantly more males' fixation points than that of females. This result can be validated like the analysis of the average fixation counts which may due to the difference cognitive processing models between male and female.

CONCLUSIONS

Analyzing people's cognitive process towards the product is anovel and effective way to evaluate people's purchase desire of the product. A study on advertisement layout showed that participants pay more time gazing on the products they prefer to buy than that of not. It means if we want to acquire consumer's point-of-purchase, we need to follow what they are focusing at. The analysis of people's cognitive processing of different Chinese style furniture whom from different background plays an important role in Chinese furniture design process, thus improving people's purchase desire of the furniture. However, further investigation is needed. The main conclusions are as follows:

(1) People tend to pay more attention to the new Chinese style furniture than the traditional one. Both the total fixation time and average fixation counts showed there was more focus on the new Chinese style furniture.
(2) When observing Chinese style furniture, females tend to take more time and have more fixation counts in the details of the furniture. However, males tend to have larger pupil diameter when observing the Chinese style furniture. Gender has a significant influence on people's cognitive processing. We should take the influence of gender into consideration when designing the Chinese style furniture to better meet particular consumers' needs.
(3) People tend to pay more attention to the decorated part of the furniture, their gaze points always stay within those areas. Thus, appropriate design and decoration both on the traditional and new Chinese style furniture could increase people's interest on them.

Exploration of people's inner visual perception of wood furniture could help designers understand what are their true needs of Chinese style furniture. In the Chinese style furniture design process, we should take advantage of the value of design of traditional furniture and new Chinese style furniture, blending them together, in order to produce furniture that are more in line with people's aesthetic preference, to improve the human living environment and to enhance the overall quality of life. Different backgrounds of consumers should be taken into consideration during the design process as well.

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