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# THE VISUAL PERCEPTION OF THE CARDBOARD PRODUCT USING EYE-TRACKING TECHNOLOGY

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## ABSTRACT

Consumers' visual perception towards the product's appearance can largely affect their preference and purchase intention of the product. Recently, the cardboard product, as a kind of environmentally friendly product, is becoming more and more popular in the market. Therefore, understanding the perception of consumers' visual evaluation toward different cardboard products is crucial for cardboard product design. This study used eye-tracking technology and subjective evaluation together to investigate people's visual perception evoked by different cardboard products. Nine different cardboard products' pictures chosen from the internet were divided into three different types and three different assembly structures. Participants were then asked to observe those pictures when their eye movement behaviors were recorded by an eye tracker. Additionally, a questionnaire about the participant's fondness and purchase of those cardboard

products were filled out after the eye-tracking test. Consumers spent less average fixation duration on the cardboard product with more usability and more familiar form to evaluate their appearances. And stronger fondness and purchase intention of those kinds of cardboard products were showed in consumers' visual perception. The exploring of the eye movement measurement on the visual perception can provide an accurate method for designers to better understanding the consumer's fondness and purchase intention of the cardboard product. Taking consumers' eye tracking metrics into account may help the product design meet their real needs in the cardboard product market.

KEY WORDS: Visual perception, eye tracking, cardboard product, product design.

## INTRODUCTION

Cardboard, as a kind of environmentally friendly material made from wood has been used wildly in our daily life (Zhu et al. 2016). With the prosper of the concept of green design in China, designers have used cardboard as a new type of material to make various products such as furniture, decorations and storage boxes etc. (Lau 2007). Those cardboard products are becoming more and more popular in the market today. However, studies about cardboard products were mainly focused on their chemical properties (Czerny and Buettner 2009, Ayrilmis et al. 2008) and mechanical properties (Abbès and Guo 2010), ignoring their psychological effect towards the consumer. As the market competition becoming fiercer today, product design largely determines the success or failure of enterprises. Evaluation of consumer's visual perception of the cardboard product in a scientific and objective way can make contributions for designers to improve their product design work.

Product's visual perception is widely considered as an important factor in the success of the process of product design (Page and Herr 2002, Kieran 1997), and has been paid close and extensive attention in recent years (Ding et al. 2017). This is because products' appearance can affect user preference and plays an important role in the procedure of consumer's purchasing decision (Guo et al. 2016, Chuang et al. 2001, Lin et al. 2007). The product's appearance is in relevant with the judgement of product quality and can influence the purchasing decision of the consumer strongly (Eldesouky et al. 2015). Therefore, the consumer tends to buy a product which could attract their visual attention at the first time (Orquin and Muelle 2013). However, product's visual perception evaluation is a combination of inherently different areas such as engineering, art and psychology (Khalid and Helander 2006, Khalighy et al. 2015), which make the evaluation procedure difficult. In the process of the cardboard product design, the visual design of the product is a relatively subjective process and the designer's personal perception plays a determinative role in the process (Yun et al. 2003, You et al. 2006).

The product's visual design decided by designer's subjective perception may not necessarily match the consumer's preference (Shang et al. 2000), thus many different methods have been used to measure the consumer's visual preference toward products. However, methods based on consumers' subjective description such as questionnaires, direct observation and focus groups cannot record their real-time affective and intuitional response (Calvert and Brammer 2012, Ding et al. 2016). Whit the development of science and technology, using physiological parameters to investigate the consumer's interest in the cardboard product has become possible.

Among those advanced technologies which could monitor consumers' physiological indexes, eye tracking is the most promising method to analyze information from what attracts consumers'

attention (Helmert et al. 2017). The evaluation results of product's visual perception from questionnaire and survey are often biased on social desirability, but the movements of eyes could provide a more direct measure of people's visual attention and collect the information about a product (Schifferstein and Desmet, 2007; Helmert et al. 2017). Researchers also found that most of the feelings evoked by a product are mediated by initial visual perception (Hogan 2001, Guo et al. 2016). Moreover, consumers' visual perception has been found as the most important sense in their product-buying process (Fenko et al. 2010). With the help of eye-tracking technology, people's aesthetic perception can be investigated experimentally without the many problems associated with conscious reporting of subjective perception (Holmes and Zanker 2012). Therefore, using eye-tracking technology can analyze consumers' visual perception towards products in a scientifically, reasonably and objectively way.

In recent years, researchers have used eye-tracking technology to investigate consumers' visual perception in many fields such as package labels, web site, traditional printed materials and living environments etc. (Ares et al. 2013, Busche et al. 2009, Rayner et al. 2001, Song et al. 2016). However, this technology was rarely used in the studies about the cardboard product and far from systematic. Using eye-tracking technology to investigate the cardboard product will help us better understanding the cognitive process and details of consumers, thus bring innovative ways to the cardboard product design and increasing the sales of cardboard-made products. As the types and structures have significant influence on the appearance of products, the visual evaluation of cardboard products should take different product types and structure into account.

This study aims to explore the consumer's visual perception of different cardboard products. Without considering the influence of the color, we just takes the appearance of the product into account. Since it is not possible to study the cognition process by eye movement index alone (Graham et al. 2012), additional methods such as questionnaires was used in this test (Mitterer-Daltoé et al. 2014).

## MATERIALS AND METHODS

Eye movement measurement and subjective evaluation were combined to analyze people's perception and purchase intention towards different types of cardboard-made products. The whole process is as follows: First, participants were asked to observe the stimuli chosen from the Internet, and their eye movement index were measured by an eye tracker during the test. Then a questionnaire was finished by the participants about their subjective evaluation of each cardboard product.

### Participant

Fifty-three healthy, right-handed student (26 males and 27 females with a mean age of 21.54 years, SD=2.17) from Beijing Forestry University were recruited as participants. No color blindness (including local and full color blindness), and without history of neurological or psychiatric disorders. All participant 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 tracker was the Ergo Lab man-machine environment synchronization platform composed of a laptop-testing computer with a 15-inch

liquid crystal display (resolution 1920*1080 pixels, 60Hz) and an eye movement module Tobii x2-60. This instrument supports computer composition optical recording pupil and corneal reflection principle (Fig. 1). The stimuli were showed on the laptop-testing computer display, and the whole process was automatically controlled by an eye movement software installed in the computer.


*Fig. 1: Eye tracker Tobii x2-60.*

## Stimuli

The stimuli were selected from websites based on the overall shape, brand and sales ranking by the authors. Consisting of 9 different cardboard - made product pictures (Fig. 2) with 3 different types (3 chairs, 3 tables and 3 decorations). Each type of the cardboard product include 3 different assembly structures, including plug-in structure (assembled and fixated by plug-in of multiple cardboard), folding structure (made by a method of folding of cardboards which have been) and space assembly structure (break down the product's form into several component and then assemble the component according to the designing demand) (Liu 2011). The stimuli were processed by Adobe Photoshop CC to grayscale images to eliminate the impact of colors on cognitive judgment. A 5-point Likert scale (1-totally disagree and 5-totally agree) was used to measure the participants' subjective evaluation with 2 items reflecting participants' fondness and purchasing intention towards the cardboard product were add (1. How much do you like this product ? , 2. How much do you want to buy this product?).

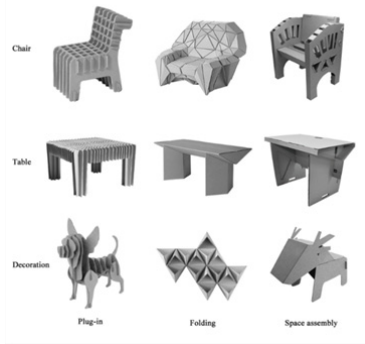


*Fig. 2: Cardboard-made products pictures in different types and assemble modes.*

## Eye-tracking measures

Before the experiment, the areas of interest (AOIs) were defined by Ergo Lab man-machine environment synchronization platform (examples see Fig. 3) to capture the eye fixation. The AOIs were defined as the "middle picture" in each stimulus. A heat map was obtained for each picture and the following eye tracking metrics were calculated using Tobii x2-60: first fixation duration (the time that first fixation lasts for each AOI), average fixation duration (duration of all

fixations within an AOI), fixation count (number of times that a participant fixated to an AOI), and average pupil diameter (pupil size is measured to reflect pupil diameter).

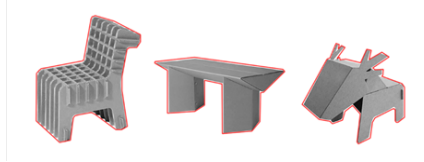

*Fig. 3: examples of the AOI in each product.*

## Procedure

To explore people's aesthetic perception and purchasing intention towards cardboard products, participants were first asked to comfortably sit in front of the computer screen with a distance of about 70 cm. Then, device recognition adjustment (of the focus of participant's eyesight) was procedure. Before the formal experiment started, participants were told to read the instruction of the test procedure. After the participant fully understood the testing requirements, stimuli were started to play on the computer screen. Before each stimulus appeared on the center of the computer screen, a blank page with a "+" symbol was shown for 30000 ms. Then the stimuli (the cardboard products pictures) randomly appeared and remained for 10000 ms of the time. In this process, participants' eye movement data was automatically collected by the eye-tracking device. After this testing, participants were asked to finish a questionnaire about their subjective evaluation towards the nine different cardboard products. The whole process lasted for about ten minutes, and Fig. 4 gives the detail.

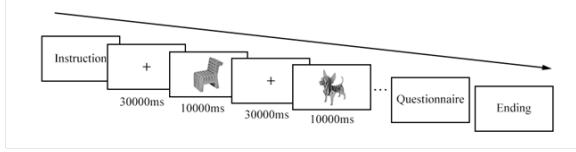


*Fig. 4: The process of the test.*

## Data processing and statistical methods

Since fixation is a time span of at least 80-100ms, fixation time shorter than 100ms in this test was exclude (Ehmke and Wilson 2007, Buscher et al. 2009). There were three independent variables in this experiment. The first variable was "Product type" and the subsets were "chair", "table" and "decoration". The second variable was "Assembly structure" and the subsets were "plug-in structure", "folding structure" and "space assembly structure". The primary object of the analysis was to test the differences of eye movement behavior and the subjective evaluation within each independent variable group (type and assembly structure) of cardboard products. The procedure of statistical method was as follows. Exploratory data analysis found that eye tracking data violated the assumptions of parametric test, hence non-parametric tests were used to analyze the raw datasets. Friedman two-way Analysis of Variance (Friedman 1937) was used to test the difference of dependent variables across repeated measurement groups. To determine which groups actually differ, post hoc analysis was implemented using Wilcoxon signed-rank tests (Wilcoxon 1945). Spearman's Rho test was implemented to explore the correlations between eye tracking metrics and subjective measures.

## RESULTS

Three participants were excluded for losing their vision in the test, final data from 50 participants (25 males and 25 females with a mean age of 21.67 years, SD=2.34) were then processed. Thirty-eight entries were removed due to measurement error, i.e. eye tracking time longer than 10000 ms or shorter than 100 ms.

### Results of heat map

The eye tacker could record the location and duration of individual's visual attention where looking at precisely with the help of the high speed camera up to 1000 times per second (Duchowski 2003). Using heat map to present the results is one of the most vivid ways. Heat map is an image generated by statistical method on the basis of subjects' eye movement data and could reflect the overall condition of duration and sight movement of the subject on screen (Pang 2013). It uses the color spectrum to indicate the location and duration where the subject fixed their attention at (Lorigo 2008). The examples of the cumulative heat map are present in Fig. 5. In the heat map, we could see the color changes from red to orange, to yellow, and then green, indicating a decreasing time of fixation. It can be seen that participants spent more time on observing the places where the main supporting structure of the product are. The rest of the duration was focus on the places where may have physical contact with human body such as the head of the animal decoration, the seat and backrest of the chair and the edge of table top. It suggested that those places in the AOIs attracted the participants' attention to a greater extent.

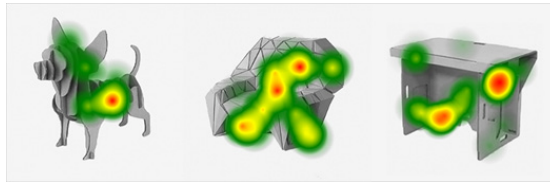

*Fig.5: Heat map example of the stimuli.*

### Eye tracking metrics in different product types

Comparison of eye tracking metrics under different product type groups is shown in Tab. 1. Significant difference was found across groups under average fixation duration ($\chi 2$ (2) =18.192, $p<0.001$) and fixation counts ($\chi 2$ (2) =9.511, $p<0.001$). Post hoc analysis with Wilcoxon signed-rank tests was conducted and the result (Tab. 2) shows average duration under chairs and decorations are significantly higher than tables. For comparison between chairs and decorations, Z=-3.119, p=0.002; for comparison between tables and decorations, Z=-0.926, p=0.355; for comparison between chairs and tables, Z=-4.137, $p<0.001$. Fixation counts under tables is significantly more than chairs; for comparison between chairs and decorations, Z=-1.159, p=0.246; for comparison between tables and decorations, Z=-1.268, p=0.205; for comparison between chairs and tables, Z=-2.466, p=0.014. No significant difference was found in other eye tracking metrics across different product type groups.

*Tab. 1: Comparison of eye tracking metrics under different product type groups.*

| Variable | Product type: mean(SD) | | | p |
|---|---|---|---|---|
| | Chairs | Tables | Decorations | |
| **Average fixation duration(s)** | 2.30 (1.36) | 1.70(1.03) | 1.80 (1.16) | <0.001 |
| **Fixation counts(n)** | 5.19 (2.63) | 6.04 (2.89) | 5.59 (2.65) | <0.01 |
| **First-time fixation duration(s)** | 2.30 (2.10) | 1.73 (1.58) | 2.02 (2.08) | 0.070 |
| **Average pupil diameter (mm)** | 3.48 (0.39) | 3.4912 (0.47) | 3.48 (0.48) | 0.837 |

*Tab. 2: Results of the analysis of the type between two groups.*

| Variable | Group comparison: Z (p) | | |
|---|---|---|---|
| | Tables- Chairs | Decorations-Tables | Chairs-Decorations |
| **Average fixation duration** | -4.137(<0.001) | -0.926 (0.355) | -3.119 (0.002) |
| **Fixation counts** | -2.466 (0.014) | -1.268 (0.205) | -1.159 (0.246) |

## Eye tracking metrics in different assembly structure

The mean difference and comparison of eye tracking metrics under different assembly structure groups is shown in Tab. 3. Significant difference was found across groups under average fixation duration ($\chi^2$ (2) = 197.875, p<0.001) and fixation counts ($\chi^2$ (2) = 52.629, p<0.001). Post hoc analysis with Wilcoxon signed-rank tests was conducted and the result (Tab. 4) shows average fixation duration under the plug-in structure and the space assembly structure is significantly higher than the folding structure. For comparison between the plug-in structure and the space assembly structure, Z=-0.395, p=0.693; for comparison between the folding structure and the space assembly structure, Z=-10.327, p<0.001; for comparison between the plug-in structure and the folding structure, Z=-9.828, p<0.001. Fixation count under the folding structure is significantly more than the plug-in structure and the space assembly structure. For comparison between the plug-in structure and the space assembly structure, Z=-1.343, p=0.179; for comparison between the folding structure and the space assembly structure, Z=-3.771, p<0.001; for comparison between the plug-in structure and the folding structure, Z=-4.436, p<0.001. No significant difference was found in other eye tracking metrics across assembly structure groups.

*Tab. 3: Comparison of eye tracking metrics under assembly structures groups.*

| Variable | Assembly structure: mean(SD) | | | p |
|---|---|---|---|---|
| | Plug-in | Folding | Space assembly | |
| **Average fixation duration(s)** | 2.05 (1.25) | 1.73 (1.12) | 2.02 (1.25) | <0.001 |
| **Fixation counts (n)** | 5.27 (2.75) | 5.94 (2.73) | 5.61 (2.73) | <0.001 |
| **First-time fixation duration(s)** | 2.27 (2.31) | 1.80 (1.51) | 1.97 (1.91) | 0.363 |
| **Average pupil diameter (mm)** | 3.51 (0.43) | 3.43 (0.45) | 3.50 (0.46) | 0.183 |

*Tab. 4: Results of the analysis of the assembly structure between two groups.*

| Variable | Group comparison: Z(p) | | |
|---|---|---|---|
| | Folding- Plug-in | Space assembly-Folding | Plug-in-Space assembly |
| **Average fixation duration** | -4.137(<0.001) | -0.926 (0.355) | -3.119 (0.002) |
| **Fixation counts** | -2.466 (0.014) | -1.268 (0.205) | -1.159 (0.246) |

## Result of subjective evaluation.

The 50 participants evaluated nine cardboard products after the eye-tracking test. Their fondness and purchase intention towards those products were measured. Mean score of fondness and purchase intention is calculated and compared across groups using non-parametric test (Friedman 1937).

Results of the product type are shown in Tab. 5, both fondness and purchase intention are differed significantly across product type groups ($p<0.001$, $p<0.001$). Post hoc testing shows that fondness under the decoration is significantly higher rated than the chair and the table groups ($p<0.001$, $p<0.001$), with no difference between category the chair and the table groups ($p = 0.337$). Purchase intention under the decoration group is significantly higher rated than the chair and the table groups ($p<0.001$, $p<0.001$), with no difference was found between the chair and the table groups ($p = 0.420$).

*Tab. 5: Comparison of subjective measurement on product type.*

| Variable | Product type: mean (SD) | | | p |
|---|---|---|---|---|
| | Chairs | Tables | Decorations | |
| **Fondness** | 3.13(1.08) | 3.04(1.06) | 3.74(1.07) | <0.001 |
| **Purchase intention** | 2.82(1.16) | 2.90(1.16) | 3.74(1.10) | <0.001 |

Results of the assembly structure are shown in Tab. 3. Both fondness and purchase intention are differed significantly across assembly structure groups ($p<0.001$, $p<0.001$). Post hoc testing shows that fondness under the folding group is significantly higher rated than the plug-in and the space assembly groups ($p<0.001$, $p<0.001$). No difference was found between the plug-in and the space assembly groups in the fondness although the plug-in group scored 0.073 points higher than the space assembly group ($p = 0.375$). Purchase intention under the folding group is significantly higher rated than the plug-in and the space assembly groups ($p<0.001$, $p<0.001$).

*Tab. 6: Comparison of subjective measurement on assembly structure.*

| Variable | Assembly structure: mean (SD) | | | p |
|---|---|---|---|---|
| | Plug-in | Folding | Space assembly | |
| **Fondness** | 3.10 (1.12) | 3.77 (0.99) | 3.03 (1.07) | <0.001 |
| **Purchase intention** | 2.88 (1.22) | 3.65 (1.04) | 2.94 (1.21) | <0.001 |

## Correlation between subjective evaluation and eye tracking metrics

No significant correlation was found between subjective evaluation and eye tracking metrics. Data shown in Tab. 7.

*Tab. 7: Correlation coefficients for subjective evaluation versus eye tracking metrics.*

| Correlation Coefficient (r) | Total fixation duration | Average fixation duration | Fixation counts | First-time fixation duration | Average pupil diameter |
|---|---|---|---|---|---|
| **Fondness** | 0.044 | 0.046 | -0.029 | 0.037 | 0.003 |
| **Purchase intention** | 0.002 | -0.021 | 0.038 | 0.025 | -0.035 |

# DISCUSSION

## Analysis of the heat map

From the Fig. 5, we see that participants spent longer fixation duration on the bracing parts of the product and on places where more likely to have physical contact with human body. Fixation duration for an image is considered as an index of process that under conscious control (Graham et al. 2011). The results indicated that participants paid more attention on the places related to their safety and body feelings, in other words, the usability and human comfort of the product. This may due to the material used in the products is cardboard which regarded as a kind of unsubstantial material by people. It is generally questioned whether the product made by cardboard can be used responsibly and comfortably. Although the heat map offers a clear visual overview, it lacks the numerical values which based on the statistical results (Lorigo et al. 2008). Therefore, further discussion based on eye tracking metrics should be taken.

## Analysis of eye tracking metrics

The general consensus in eye movement research is that the fixation duration and fixation count are more helpful for analyzing consumers' engagement and mental processing in the process of their visual evaluation (Rayner 1998). The average fixation duration varies was considered as a index to evaluate the difficulty of the music. The research results showed that the music with more difficult selections have led to longer fixation than easier selections (Weaver 1943). Moreover, longer average fixation duration means people are spending longer time on the local processing (Cowen et al. 2002). The results show that average fixation duration in the chair and the decoration product are significantly higher than the table's. Compared with the chair and the decoration, the table is a kind of product with simpler form of structure. Consequently, the chair and decoration with higher complexities led to longer average fixation duration so that the participant were able to observe the product details more carefully.

Some studies have shown that fixation count is fewer when participants experience a positive emotion (Gao and Sui 2012), and have a negative correlation with valence ratings (Guo et al. 2015), while other studies showed that fixation count showed positive correlation with human evaluation (Doherty et al. 2010). Tuch et al. believed that the relationship between subjective emotional ratings and eye tracking metrics remained elusive (Tuch et al. 2011).

So it is hard to conclude that there exists inevitable connection between the fixation count and the consumers' emotion. In the current experiment, the result of the fixation count in the table product is greater than that of the chair and decoration, which may due to the fact that observing time for each stimuli in this test was fixed. As the table with simple forms and structure had shorter average fixation duration, participants tend to distribute their attention to other parts of the product which led to more fixation counts.

The results show that average fixation duration in the folding structure is significant shorter than that of the plug-in and space assembly structures. For the fixation count, the folding structure is significantly more than that of the plug-in and space assembly structures. These results are similar to the discussion on the different cardboard product's types that the stimuli in a group with less average fixation duration had greater fixation counts. According to the research from Pieters et al., eye-tracking data is a sensitive index to reflect the familiarity of the subject for the stimulus (Pieters et al. 1999). Generally, people are accustomed to reconstruct paper materials in the way of folding. Cardboard, as a kind of paper materials, may also have this character of easy to fold in participants' views. We could speculate that, compared with the other two cardboard products' assembly structures (plug-in structure and space assembly structure), participants are

more familiar with the folding-structured cardboard product. So the results of eye tracking metrics of different assembly structures could be explained by the view that while participants are more unfamiliar with the stimulus, longer average fixation duration will be spend on the details of the stimuli, and resulting in fewer fixation count in a fixed observation time.

### Analysis of the subjective evaluation

For the type of the cardboard products, participants' fondness and purchase intention to decorations are significant higher than chairs' and tables'. Many design features affect the evaluation of products' usability such as size and form (Mugge and Schoormans 2012). As the chair and the table are products with bigger size that require higher structural strength than the decoration for the people to use, participants may have less confidence in those products' usability. On the other hand, participants' fondness and purchase intention to folding structure are significant higher than that of the plug-in structure and the space assembly structure. This result can be explained by the view from the previous section that participants are more familiar to the folding structure, therefore, result in higher fondness and purchase intention to the cardboard product with this kind of structure.

## CONCLUSIONS

This study uses eye-tracking technology to investigate people's visual perception towards the cardboard product. Although no significant correlation was found between subjective evaluation and eye tracking metrics in this test. This method proved to be a promising tool for better understanding of the visual perceptions of the consumer towards cardboard products. With the use of eye-tracking technology, consumers' visual perceptions towards the cardboard product could be analyzed in a more objective way and allows designers have more insight into consumer's behavior. The main conclusions are as follows:

(1) Consumer's visual attention towards the cardboard product focused more on the place which related to their safety and body feelings such as the bracing parts of the product and places may have physical contact with human body. They tended to spend longer fixation duration on those places to evaluate the usability and comfort of the cardboard product.
(2) Cardboard products with simpler and more familiar appearances will spend consumer less average fixation duration for consumers to observe their details.
(3) The consumer showed stronger fondness and purchase intention to the cardboard product with familiar forms. On the other hand, for the new product such as the cardboard product, consumers showed stronger fondness and purchase intention to the product with better usability and reliability.

There are also some limitations in this study. Firstly, the present study was limited to explain the inner interaction between the eye movement behavior and different cardboard product, due to the classify of the cardboard product is still far from systematic. Secondly, there are significant eye movement differences between males and females in the process of visual perception in the literature (Andersen et al. 2012). Further research should take gender and other different background variables such as age and major of the consumer into account.

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