KANSEI DESIGN OF LCD PANEL SPECIFICATIONS

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ABSTRACT

Even though liquid-crystal displays (LCD) have become a part of our life, the technology-oriented specifications for panels left consumers with difficulty to get close to and understand them. Applying Kansei Engineering approach and Design of Experiment (DOE) method, this study tried to measure users' feelings about the designs of LCD displays and the relationships between the specifications of LCD panels and Kansei evaluations efficiently. The results of this study could help designers understand consumers' Kansei preferences of LCD displays, and choose the most appropriate LCD panels to achieve better overall display design. By proposing a Kansei specification for the LCD panels that assures a user-friendly interface, the results of the study would also provide manufactures a reference for developing new technology of LCD panels. The results of this study show as follows: (1) Users' Kansei words of LCD panel specifications could be extracted as 8 representative Kansei words including Bright, Sharp, Vivid, Comfortable, Natural, Graceful, Friendly, Energy-saving. (2) Contrast Ratio of LCD panel specification is the most significant to drive the positive feeling and image, followed as Resolution and Gamut. (3) Contrast ratio, gamut and resolution have significant influence to Kansei word "Energy-saving" with negative relationship. (4) The predicted equations are confident by test, and could be used as reference for user-friendly interface.

Keywords: *Kansei Engineering, Kansei Evaluation, LCD Panel Specifications, LCD Displays*

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1. INTRODUCTION

The development of liquid crystal display (LCD) industry continues flourishing, even though going through the global financial crisis in 2008 and 2009. The demand of a single quarter in 2009 Q1 for large-size panels (panel demand volume) was still 84,442 thousands/quarter, and the quarter growth rate was 14.7% since the global financial crisis [11]. In addition to the demand and the growth rate of TFT LCD displays, we can also sense the trend of global popularity for LCD. For example, due to the environmental issues, LCD displays are proposed to replace cathode ray tube (CRT) displays [2]. Thus, while LCD becoming almost a necessity for daily life, the technology-oriented specifications for panels left consumers with difficulty to get close to and understand them. Up to the most recent, most of studies focused on the technology, engineering management or industrial development of LCD's, but rarely made users to understand by direct feelings other than technical specifications. Kansei Engineering (KE) is a method designed to understand and translate desired feelings and impressions into design elements [1]. Hence, KE was employed in this study, and in consequence, LCD panel specification was expected to be designed to bring forward the intended feelings of users.

1.1. Purposes and Objectives

The purposes of this study were set to measure users' feelings about the designs of LCD displays and the relationships between the specifications of LCD panels and Kansei evaluations. The objectives could be drawn as follows: (1) To understand consumers' Kansei preferences of LCD displays. (2) To replace or modify the conventional technical specifications based on the findings. (3) To assist designers to choose the most appropriate LCD panels to achieve better overall display design. (4) To assure a user-friendly interface by proposing a Kansei specifications for the LCD panels. (5) To provide manufactures a guide for developing new technology of LCD panels.

1.2. Process and Steps

This study employed Kansei Engineering approach. Interviews, questionnaires and experiments were conducted along with the procedures of Kansei evaluations which can be divided into following steps [1]: (1) collecting Kansei words and illustrations of LCD panel specifications; (2) selecting Kansei words and representative specifications of LCD panel by interview with experts and questionnaires; (3) extracting design elements; (4) designing questionnaires with 5-level of SD method; (5) conducting experiments with questionnaires in Taiwan; (6) analyzing results using Multiple Regression [9]; (7) verification by questionnaires, linear regression and nonlinear regression.

1.3. Subjects and Scope

The general LCD panel specifications and pictures of global LCD manufacturers from Taiwan, China, Japan and Korea are used as reference for this study [11]. The subjects are popular LCD panels, not including special applications, avionics and medical applications for example. The matrix of LCD was designated as active Thin-Film-Transistor (TFT), and the view-angle was specified as front view. And the questionnaire survey was conducted in Taiwan.

2. THEORETICAL BASES

Related researches and literatures including LCD studies, design of experiment (DOE), and Kansei engineering are reviewed in order below to form the foundation for this study.

2.1. LCD Displays Studies

2.1.1. LCD Displays History and Principle

In the past, TV and computer monitors used cathode ray tubes (CRTs) which were bulky with limited screen size, radiation and other shortcomings. Along with the development of electronic technology, the requirements for the mobile display are getting greater. The inherent limitations of CRTs should be solved eventually. To develop a new generation of display technology has become essential [4]. That is why LCD displays could win the game.

The development of LCD Displays began in 1964. Kawamoto [4] provided the details of the history and principle. In Taiwan, there are such as AUO, CMO, CPT, and Hannstar Display to invest into the development of manufacturing technologies such as process automation and optimal control for large area lithography on the panel glass. Currently, Korea, Taiwan, Japan and China are the major countries for making the TFT-LCD's [11]. Briefly, a TFT LCD is a device controlled by electric signals. It uses liquid crystal to control the passage of light between two glasses. The front glass substrate is fitted with a color filter and the back glass substrate has transistors fabricated on it. The direction of the LC molecules directly affects the penetration level of the light source. Then, it in turn creates the desired lightness and darkness in the image, also known as gray scale. Color is produced by the color filter substrate to mix the light. Gray scale of a pixel is decided by designated voltage levels from the data driver. The combination of these pixels in different colors makes the image on the panel. The principle and structure of LCD will deliver and affect the LCD panel specifications [2].

2.1.2. LCD Panel Specifications

The general specifications of LCD panel are as follows [2, 4]: (1) Viewable size: LCD screen can display as part of the display area (Active Area), the size of LCD panel is the length of measurement on the diagonal. (2) Aspect ratio: the aspect ratio of display = (display height / display width); (3) Color depth: Color depth is one aspect of color representations, expressing how finely levels of color can be expressed. The other aspect is how broad a range of colors can be expressed. For instance, 8-bit color depth = 28x28x28 = 16,777,216 (16.7 million colors). (4) Resolution: liquid crystal displays are composed of a number of red light (R), green (G), blue (B) color sub-pixel (dots), while R+G+B being called a pixel. The horizontal and vertical size expressed in pixels (e.g., 1920x1080). (5) Pixel pitch: It refers to the distance between the centers of two adjacent pixels. The smaller the pixel pitch, the less granular image is present, and resulting in a sharper image. Pixel pitch may be the same both vertically and horizontally, or different (less common). It also can be showed by another way as Pixel Density (Pixels per inch / PPI). The PPI of a LCD panel is related to the size of the display in inches and the total number of pixels in the horizontal and vertical directions. (6) Brightness: The amount of light emitted from the display, the unit is nits (cd/m2). (7) Contrast ratio: Contrast ratio = (brightness of bright state) / (brightness of dark state). (8) Color gamut: color LCD display RGB ability to define the size of = NTSC/RGB space. (9) Response time: with "milliseconds (ms)" as a unit, the fewer the number of seconds of reaction time on behalf of the faster, the screen is relatively smooth. (10) Viewing angle: The viewing angle is the angle formed on either side of the viewing direction, where the contrast of the display is still considered acceptable. (11) Refresh rate: The number of times per second in which the LCD panel draws the data being given. Since activated LCD pixels do not flash on/off between frames, LCD monitors exhibit no refresh-induced flicker, no matter how low the refresh rate.

2.2. Design of Experiment (DOE)

Design of Experiments (DOE) is a statistical technique for quickly optimizing performance of systems with known input variables. The purpose of DOE is to find out the critical factors that affect the results and decreasing the cost and time of trials and errors. Uy [9] delivered the principle of DOE and presented some examples to show that DOE had been effectively applied in many fields in collecting useful information based on designed experiments [5,6]. DOE consists of two parts as design and analysis. By a factorial design, we mean that in each complete trial or replication of the experiment all possible combinations of the levels of the factors are investigated. When the numbers of factors increase to a degree, the experimental numbers will be largely increased. Comparing to that, fractional factorial designs are becoming much economic and very effective methods. On the other hand, the analysis of Mintab DOE can unveil the interactions of participated specifications. That is why this experiment considered using fractional factorial designs to implement the experiments of this study instead of other methods for selecting representative experiment samples which are representative of specific designs, but might not be systemic enough.

3. PROCESSES

The study was conducted with the following steps [1]: (1) collecting Kansei words and pictures of LCD panel specifications; (2) selecting representative Kansei words and LCD panel specifications; (3) extracting design elements; (4) designing questionnaires; (5) conducting experiments; (6) analyzing results; (7) verification.

3.1. Collecting Kansei Words and Pictures of LCD panel Specifications

The most popular Kansei words used in describing LCD panels are collected from articles, newspaper, web pages and magazines published in Taiwan. It also could be gained from the talk among sales and customers in the street market. There are about 200 adjectives selected for Kansei words. On the other hand, pictures of LCD panel specification in the street market and websites are extensively collected as well. The pictures collected from current media can only explain the effect by one specification of LCD panels. In other words, the interaction of variables by more specifications cannot be presented by the current collection. Thus, these pictures of LCD panel specification are only for reference to make experiment samples for next step.

3.2. Selecting Representative Kansei Words and LCD Panel Specifications

60 adjectives of the first tier were selected after the questionnaire by 15 experts (Product development engineers) in LCD manufacturers. Then, a questionnaire on Google Docs was made and 21 representative Kansei words out of 60 in the second tier were selected by 30

participants in Taiwan. As the aim of this study was to find out the relationship between users' feeling and LCD panel specifications that were regarded as different factors to affect the users' feeling. Design of Experiment (DOE) could arrange an efficient experiment and select representative samples. General LCD panel specifications include: Viewable Size, Aspect Ratio, Color Depth, Resolution, Dot pitch, Brightness, Contrast Ratio, Color Gamut, Response Time, View Angle, Refresh rate and so on. After interviewing with LCD experts, some specifications with similar display effect will be extracted as a representative specification, even though the physical definition and principle are different respectively. The final representative specifications include 6 items: Aspect Ratio, Resolution, Brightness, Contrast Ratio, Gamut and Response Time. These 6 main specifications are all examined from front view, not including view-angle specification of LCD panel.

3.3. Extracting Design Elements

A list of design components (equivalent to items in KE) and design options (equivalent to categories in KE) was complied after Morphological analysis. Table 1 shows the results.

3.4. Designing Experiment

From the result of Morphological analysis of LCD panel specifications, we applied fractional factorial design to conduct more efficient experiments. Table 2 shows the fractional factorial design table with 1/4 factorial design, 16 runs for 6 factors.

The independent variables of this experiment include Aspect Ratio, Resolution, Brightness, Contrast Ratio, Gamut and Response Time. The dependent variables of this experiment are the representative Kansei words which are selected from previous steps.

The control variables are shown as follows.

Experiment Environment : The experiment environment was simulated as an office space, the brightness was set as 400 lux to 500 lux; color temperature was about 5000K. The participants observed the experiment pictures vertically with the LCD panel and the distance between observers and the LCD panel is 30cm to 50cm.

Experiment Picture : To decrease the noise from experiment variables, the experiment picture was set as a static picture with tropical fishes which is due to presenting the motion effect for response time. The size of the picture is 800 pixels * 450 pixels with 72 dpi. Considering the real scenario, the experiment was conducted with the 26" LCD display.

3.5. Conducting Experiments

The experiment was conducted with 21 adjective-pairs and 16 test samples. These 16 experiment samples were presented to 30 participants. The participants were asked to express their Kansei feelings in 5-level of SD scale, which was enhanced by programming to drag and categorize samples intuitively [3]. The programming interface set all experiment pictures together and let users drag and put down for SD scale freely. It tried to improve the users' memory and help participants to distinguish the difference between each picture easily.

Table 1: Design Elements

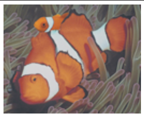
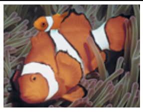
Items		Categories	
Geometry	Aspect Ratio A	5:4 A1 	16:10 A2 
	Resolution R	High R1 	Low R2 
Optics	Brightness B	High B1 	Low B2 
	Contrast Ration C	High C1 	Low C2 
	Gamut G	High G1 	Low G2 
	Response Time T	Quick T1 	Slow T2 

Table 2: Fractional Factorial Design Table

Run Order	Aspect Ratio	Resolution	Brightness	Contrast Ratio	Gamut	Response Time
1	1	-1	1	-1	-1	1
2	1	-1	1	1	-1	-1
3	1	-1	-1	-1	1	-1
4	-1	-1	-1	1	-1	1
5	-1	1	-1	1	1	-1
6	1	1	1	-1	1	-1
7	-1	-1	1	-1	1	1
8	-1	1	1	-1	-1	-1
9	-1	1	-1	-1	1	1
10	-1	-1	1	1	1	-1
11	1	1	-1	1	-1	-1
12	1	-1	-1	1	1	1
13	1	1	-1	-1	-1	1
14	-1	-1	-1	-1	-1	-1
15	1	1	1	1	1	1
16	-1	1	1	1	-1	1
Note: (1) 1 means high (quick) level; -1 means low (slow) level; (2) CenterPt and Blocks are set to 1.						

3.6. Analyzing Results

From the results of factor analysis as shown in Figure 1, 5 factors could be extracted which eigenvalue is greater than 1.0 respectively. Figure 2 shows the image space of LCD specifications as Human-optical factor, Environment-interaction factor, Atmosphere factor, Affection factor and Physical factor. From the results of cluster analysis with Ward linkage method, these 21 Kansei words could be clustered as 6 groups. Considering the results of Factor Analysis and Cluster Analysis, and the practical requirements of LCD panel simultaneously, 8 final representative Kansei words are coming out for further analysis as Bright, Sharp, Vivid, Comfortable, Natural, Graceful, Friendly, Energy-saving. We can achieve the predicted equations for the relationship between Kansei words and LCD panel specifications by the results of Kansei evaluation and analysis. The results of Multiple Regression were shown in Tables 3 and 4, which depicts one of eight representative Kansei words.

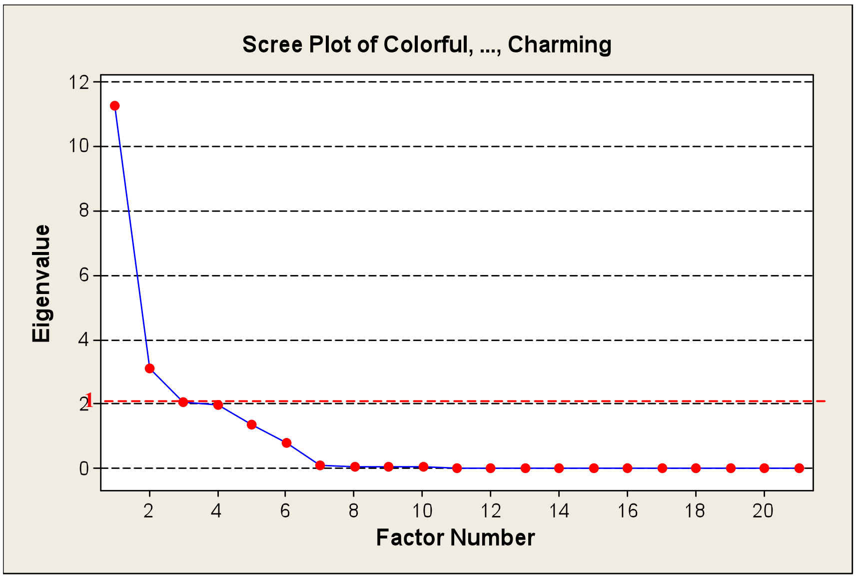


Figure 1: Screen Plot of Factor Analysis

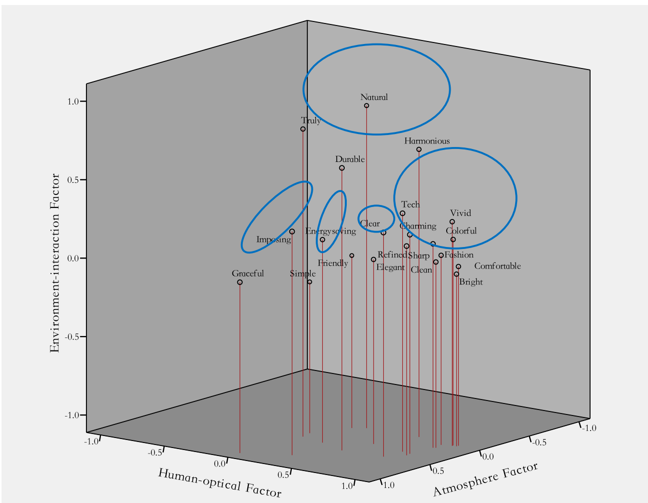


Figure 2: Image space of LCD specifications

3.6.1. Multiple Regression

Table 3 shows the results of Multiple Regression. Only the R-Sq(adj) of Energy-saving is greater than 70%.

Table 3: The regression equations from Multiple Regression

Kansei words	**Regression Equations**							**R-Sq**	**R-Sq(adj)**
	Constant	A1	R1	B1	C1	G1	T1		
Bright	0.351	0.291	0.484	0.284	1.059	1.091	0.324	81.1%	68.5%
Sharp	0.496	0.066	0.511	0.234	0.944	0.944	0.351	70.4%	50.7%
Vivid	1.074	-0.051	0.589	0.054	0.761	0.764	0.346	71.4%	52.3%
Comfortable	0.871	0.095	0.880	0.088	0.548	0.403	0.490	74.2%	57.0%
Natural	1.225	0.228	0.830	-0.095	0.338	0.173	0.448	67.9%	46.4%
Graceful	2.175	0.080	0.225	0.150	0.200	0.190	0.190	50.5%	17.5%
Friendly	1.671	0.149	0.371	0.371	0.539	0.429	0.104	74.7%	57.8%
*Energy-saving	3.513	0.035	-0.160	0.193	-0.648	-0.368	0.165	88.9%	81.5%
* mark represents R-Sq(adj) > 70%.									

3.6.2. Minitab analysis

Table 4 shows the coefficients for Natural which is one of 8 Kansei words from Minitab analysis. Each R-Sq(adj) of the rest 7 Kansei words is greater than at least 86% respectively as well, the confidence of predicted equations are high.

Table 4: The coefficients for Natural from Minitab analysis

Term	**Coef**	**P**
Constant	2.18500	0.000
Aspect Ratio	0.11375	0.003
Resolution	0.41500	0.000
Brightness	-0.04750	0.038
Contrast Ratio	0.16875	0.001
Gamut	0.08625	0.008
Response Time	0.22375	0.000
Aspect Ratio*Brightness	0.15625	0.001
Aspect Ratio*Gamut	0.04750	0.038
Resolution*Contrast Ratio	0.24875	0.000
Resolution*Response Time	0.19375	0.001
Aspect Ratio*Resolution* Contrast Ratio	0.03500	0.080
Aspect Ratio*Resolution* Response Time	0.04000	0.058
R-Sq = 99.87% ; R-Sq(adj) = 99.33%		

Table 5: 2 sample Test from Multiple Regression and experiments

Kansei words	T	DF	P-Value	Difference	95% CI for difference	
					Lower Bound	Upper Bound
Bright	0.33	8	0.752	0.278	-1.682	2.238
Sharp	0.55	8	0.594	0.430	-1.356	2.215
Vivid	0.35	8	0.737	0.255	-1.440	1.951
Comfortable	0.14	8	0.891	0.115	-1.748	1.978
Natural	0.30	8	0.769	0.226	-1.495	1.948
Graceful	-0.35	4	0.745	-0.211	-1.891	1.469
Friendly	-0.04	8	0.969	-0.026	-1.525	1.474
Energy-saving	-0.71	8	0.497	-0.131	-0.557	0.294

Table 6: 2 sample Test from DOE analysis and experiments

Kansei words	T	DF	P-Value	Difference	95% CI for difference	
					Lower Bound	Upper Bound
Bright	-0.14	8	0.893	-0.128	-2.265	2.009
Sharp	-0.21	8	0.841	-0.180	-2.172	1.813
Vivid	-0.01	8	0.991	-0.009	-1.781	1.764
Comfortable	0.05	8	0.959	0.044	-1.877	1.965
Natural	-0.06	8	0.954	-0.045	-1.797	1.706
Graceful	0.48	8	0.644	0.302	-1.149	1.753
Friendly	0.17	8	0.867	0.121	-1.495	1.737
Energy-saving	0.55	8	0.599	0.101	-0.326	0.529

3.7. Verification

The verification experiment was conducted with the 8 Kansei words and 5 samples. These 5 experiment samples were presented to 5 participants respectively and these participants were asked to score their Kansei evaluation in 5-level of SD method. On the other hand, the parameters of these 5 samples were taken into the equations of Multiple Regression and Minitab respectively for calculating the predicated value of each Kansei word. The average difference between Multiple Regression and experiments was –0.11 and the average difference between Minitab analysis and experiments was 0.03. The results of 2 sample Test are shown as Tables 5 and 6.

4. CONCLUSIONS AND DISCUSSIONS

Applying Kansei Engineering to LCD panel industry is not a brand-new concept, but could be a breakthrough. Human's visual feeling is foundamental to LCD optical theory, but most of them focused on the distinctions of colors and lightness which belong to the physical perception. Kansei Engineering can complement psychological aspects with consumer-oriented design to LCD panel industry. Employing Kansei Engineering approach, this study tried to measure users' feelings about the designs of LCD displays and the relationships between the specifications of LCD panels and Kansei evaluations. The results of this study could help designers understand consumers' Kansei preferences of LCD displays, and choose the most appropriate LCD panels to achieve better overall display design. By proposing a Kansei specification for the LCD panels that assures a user-friendly interface, the results of the study would also provide manufactures a reference for developing new technology of LCD panels.

The results of this study are summarized as follows: (1) Users' preference for LCD panel specifications can be classified as 8 representative Kansei words, including: bright, sharp, vivid, comfortable, natural, graceful, friendly and energy-saving. (2) Contrast Ratio of LCD panel specification is the most significant to drive the positive feeling and image, followed by Resolution and Gamut. (3) Contrast ratio, gamut and resolution have significant influence to Kansei word "Energy-saving" with negative relationship. (4) The predicted equations of Kansei values from Multiple Regression and Minitab are confident by test, and could be applied to the user-friendly interface. The results could be used as reference for the world-wide LCD manufacturers as well, even though the experiments were implemented in Taiwan.

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