Evaluation of Innovative Design for Battery Electric Vehicle Center Console Based on Kansei Engineering

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Abstract: With the growth of new energy vehicles, competition in the auto industry is fierce. Automotive brands must continuously seek innovative design solutions to secure their market position. Which BEVs offer more design freedom, particularly in interior design, as they don't require considerations for fuel engines and related components. However, with the arrival of the era of personalized consumption, what kind of design exploration can be accepted by consumers is still under study. Therefore, this research uses Kansei engineering theory to study the center console of BEVs, collect and select representative images sample and perceptual vocabulary of BEV center console, counts the mean value of users' perceptual evaluation through market research, establishes the response matrix of design elements based on quantitative theory I, and uses multiple linear regression analysis to obtain the influence relationship between each design element and users' perceptual imagery, so as to evaluate innovative design results of the BEV center console. The research results indicate that different center console design elements have a significant difference in the degree of influence on user sensory imagery. The connection transition method between the center console and armrest box has a significant impact on the user's perception of the simplicity. The usage method of the center screen and the color matching will have a significant impact on its futuristic.

Keywords**:** Battery Electric Vehicle; the center console; Kansei Engineering; Perceptual imagery; Design Innovation

1. Introduction

The energy challenge is hindering global economic growth, prompting countries to advocate for a green lifestyle. New energy vehicles, such as Battery Electric Vehicles (BEVs), represent a low-carbon economy and have become a key focus for governments and manufacturers. BEVs are the most popular type due to their low energy consumption, minimal noise, and zero emissions. According to a report released by the International Energy Agency (IEA) [1], as of 2021, there were over 10 million

BEVs on the road worldwide, and over 400 models available for sale globally. To stay competitive, manufacturers must continuously improve their innovation capabilities, explore new design solutions, and attract consumers with unique designs.

Compared to exterior design, interior design for BEVs offers more creative freedom due to the absence of fuel engine components and traditional devices like instrument panels and fuel gauges. This also allows emerging brands to adopt innovative styling features [2]. However, there is a risk that new features may not be accepted by consumers, and little research has been done on this issue. With personalized consumption on the rise, consumers prioritize their sensory and emotional experiences when selecting products. The center console is a critical component of a car's interior design, and a well-designed structure can enhance the driving experience and sensory satisfaction. This study focuses on the center console in BEV interior design, analyzing the relationship between its design elements and consumers' perception using Kansei engineering. By evaluating the innovative achievements in the BEV industry, this study provides a reference for future design innovation, with significant theoretical value for guiding the direction of BEV design.

2.Kansei Engineering

Kansei Engineering is a theory and method that can effectively capture consumers' emotional needs and experiences towards products and quantify them [3]. The advantage of using this approach is that it provides objective design evaluation criteria, which helps to avoid subjective evaluation defects and enhances the credibility and persuasiveness of the evaluation results. By applying Kansei Engineering to the center console of BEVs, this study can provide scientific and reasonable guidance and reference for the design evaluation of BEV interiors.

3.Methodology and process of the study

3.1. Collecting BEV center console design samples.

This study collected 87 valid samples of central console styling for BEVs from various channels, using image recognition technology and cluster analysis. The 16 central console styling images with the highest similarity to the cluster centers were chosen as samples, and the accuracy and completeness of the selection results were verified by three automotive design industry professionals and two industrial design teachers. The images were processed to remove brand logos, and numbered for further analysis. The results are presented in Figure 1.

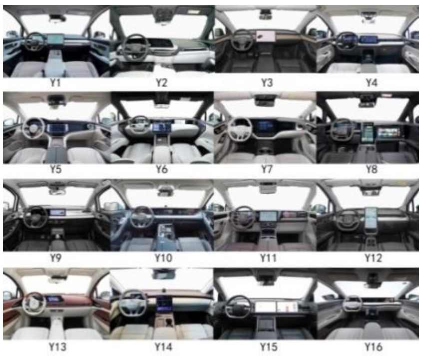

Figure 1. Typical Sample Library of BEV Center Console

3.2. Extraction of BEV center console design elements

This study used an image processing and computer vision algorithm to extract key design elements of BEV center consoles, design categories were summarized and coded in Table 1.

3.3. Extraction and selection of perceptual vocabulary

We collected 65 emotional vocabularies related to center console from brand positioning reports, and automobile information platforms. After classification and organization, we paired the remaining vocabulary with antonyms and identified 5 representative sets of emotional vocabulary in Table 2.

Table 1. Classification and Coding Table of Design Elements

Design elements	Design category		
Exterior Profile Curve（X_1）	Streamlined（C_{11}）	Geometrical（C_{12}）	
Armrest box connection.（X_2）	Organic Connection（C_{21}）	Split-Type Connection（C_{22}）	Control Screen（C_{23}）
Instrument Panel（X_3）	Square-Shaped（C_{31}）	Rounded Shape（C_{32}）	No dashboard（C_{33}）
Central Control Screen（X_4）	Normal horizontal screen（C_{41}）	Normal vertical large screen（C_{42}）	General Multi Screen（C_{43}）
	Left duplex screen（C_{44}）	Right duplex screen（C_{45}）	Triplex Screen（C_{46}）
Joint Screen Modeling（X_5）	Square-Shaped（C_{51}）	Rounded Shape（C_{52}）	Heterotypic（C_{53}）
Screen Connection（X_6）	Suspended（C_{61}）	Embedded（C_{62}）	
Color Matching（X_7）	Dark Tones（C_{71}）	Bright Tones（C_{72}）	Colorful（C_{73}）

Table 2. Perceptual Vocabulary

Minimalistic—Complex	Streamlined—Rigid	Personalized—Common
Fashionable—Outdated	Futuristic—Conventional	

3.4. Assessment of perceptual imagery

This study employed the SD method to evaluate the emotional image of the central console, using a 7-point Likert scale questionnaire. A total of 74 valid responses were collected from the target population, and the questionnaire's reliability was analyzed using SPSS software, resulting in a value of 0.947, indicating good reliability. The emotional evaluation mean value of representative samples was calculated and presented in Table 3.

Table 3. Average value of perceptual evaluation

Sample number	Minimalistic—Complex	Fashionable—Outdated	Streamlined—Rigid	Futuristic—Conventional	Personalized—Common
Y1	1.12	0.82	0.17	0.47	0.76
Y2	-0.76	-0.05	0.34	-0.15	0.18
…	…		…		…

Y15	2.06	0.74	0.29	1.14	0.47
Y16	2.13	1.68	0.97	1.87	0.88

3.5. Principal Component Analysis

This study conducted principal component analysis to reduce the dimensionality of data and identify key sensory words [4]. KMO and Bartlett's tests were performed to ensure the feasibility of the analysis, as shown in Table 4. Two factors with eigenvalues greater than 1 were extracted in Table 5, explaining 81.909% of the total variance. The maximum variance rotation method was used to find the correlation between factors and research items, and “minimalistic” and “futuristic” were identified as the two key sensory words, as shown in Table 6.

Table 4. KMO and Bartlett’s test

KMO	0.747	
Bartlett’s Test of Sphericity	Approx. Chi-Square	43.583
	df	10
	P	0.000

Table 5. Total variance explained

Component	Variance explained before rotation.			Variance explained after rotation		
	eigenvalues	% Of Variance	Cumulative %	eigenvalues	% Of Variance	Cumulative %
1	3.502	70.036	70.036	223.214	44.643	44.643
2	1.594	11.872	81.908	186.328	37.266	81.908
3	0.487	9.74	91.649			
4	0.324	6.488	98.136			
5	0.093	1.864	100			

Table 6. Table of factor loading coefficients after rotation

	Minimalistic—Complex	Fashionable—Outdated	Streamlined—Rigid	Futuristic—Conventional	Personalized—Common
Factor 1	0.279	0.521	0.687	0.842	0.838
Factor 2	0.938	0.811	0.397	0.307	0.272

3.6. Multiple Linear Regression Analysis

Based on the ideas of Quantification Theory I, the design elements of the central console styling were set as the items, the subclasses under the design elements were set as the categories, and the mean scores of sensory evaluation were set as the dependent variables [5]. The design element response matrix of 16 representative samples was obtained as shown in Table 7.

Table 7. Reaction matrix

Sample	C_{11}	C_{12}	C_{21}	…	C_{62}	C_{71}	C_{72}	C_{73}
Y1	0	1	0	…	0	0	0	1
Y2	1	0	0		0	0	1	0
…		…					…	
Y15	0	1	1	…	0	1	0	0
Y16	1	0	0		0	0	1	0

The data was imported into SPSS software for multiple linear regression analysis. Taking

"Minimalistic—Complex" as an example, the significance P value was obtained through the analysis of the F value, which is $0.021<0.05$, indicating that there is a significant and linear relationship between variables horizontally, and can be used for linear regression analysis. Then, the standardized coefficient, partial correlation coefficient, determination coefficient, multiple correlation coefficient, and constant term were calculated separately, and the results are shown in Table 8.

Table 8. Statistics of linear relationship analysis results

items	Categories	Minimalistic—Complex		Futuristic—Conventional	
		Partial correlation coefficient	standardized coefficient	Partial correlation coefficient	standardized coefficient
X_1	C_{11}	0.429	-0.265	0.113	0.315
	C_{12}		2.18		0.21
X_2	C_{21}	0.364	-0.347	0.145	-0.015
	C_{22}		1.083		0.125
	C_{23}		0.006		0.095
X_3	C_{31}	0.124	0.266	0.105	0.128
	C_{32}		0.193		-0.067
	C_{33}		0.456		0.148
X_4	C_{41}	0.187	0.291	0.537	-0.019
	C_{42}		0.152		0.068
	C_{43}		-0.583		0.145
	C_{44}		0.107		0.169
	C_{45}		0.191		0.281
	C_{46}		0.161		0.543
X_5	C_{51}	0.223	0.321	0.204	0.112
	C_{52}		0.018		0.015
	C_{53}		-0.097		0.204
X_6	C_{61}	0.253	0.331	0.153	0.105
	C_{62}		0.201		0.118
X_7	C_{71}	0.310	0.196	0.366	-0.034
	C_{72}		0.387		0.314
	C_{73}		0.223		0.449
		constant term	0.915	constant term	0.533
		R	0.940	R	0.983
		R^2	0.884	R^2	0.966

4. Results and Validation

To validate the results, "Minimalistic—Complex" was taken as an example. The method of arranging and combining design categories with different scores was used to obtain multiple new combination schemes to validate the results. First, the highest scoring categories C_{12}, C_{22}, C_{33}, C_{45}, C_{51}, and C_{61} were used to create combination scheme 1. The higher scoring categories C_{12}, C_{23}, C_{31}, C_{44}, C_{52}, and C_{61} were used to create combination scheme 2. Then, the lowest scoring categories C_{11}, C_{21}, C_{32}, C_{43}, C_{53}, and C_{62} were used to create combination scheme 3, as shown in Figure 2.

Figure 2. Portfolio Solutions

The SD method was used to create a questionnaire for the three new combination schemes. Driving experienced users in the design industry were invited to evaluate the sensory image of the schemes to ensure accuracy. After analyzing the 28 valid questionnaires collected, mean values were calculated and shown in Table 9. The results demonstrated that the sensory image scores of Scheme 1 to Scheme 3 decreased, confirming the research conclusion's accuracy and validity.

Table 9. Portfolio Solutions perceptual evaluation means

Scheme	Scheme 1	Scheme 2	Scheme 3
Average	1.82	0.95	0.21

5.Conclusions

This study applies Kansei engineering to establish the relationship between design elements of BEVs center console and consumers’ perceptual imagery.

1. The research discovered that various design elements of the center console have varying impacts on users' perceptual images. For instance, the center console's overall contour curve and the transitional connection of the armrest box significantly affect the perception of simplicity, while the center console screen's shape and the color matching have a higher impact on its sense of futurism.

2. The research found that the armrest box to center console transition has a significant impact on the center console's simplicity, likely due to the simpler functional requirements in BEVs. The split connection method, which is popular in BEVs, scored high in simplicity and supports this conclusion, as it simplifies the center console's structure by abandoning the complex operation panel.

3. The research suggests that the dual-screen and triple-screen layouts commonly used in BEVs give consumers a stronger sense of futurism and technology compared to the traditional layout of separate instrument panel and center console screens in fuel vehicles.

4. The study developed a predictive model for evaluating the design innovations of BEV center consoles and guiding future designs, but the research's limitation is that only images were used to evaluate the center console design. Future research should include real samples and integrate Kansei engineering with other design methods to conduct a more comprehensive product design analysis.

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