Digitalization and Management Innovation III
A.J. Tallón-Ballesteros (Ed.)

doi:10.3233/FAIA250065

Bionic Furniture Design Based on Digital Quantification Research: Application of Semiotics and Semantics

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Abstract. This study aims to explore the application of semiotics and semantics in bionic furniture design, incorporating digital quantitative research methods to uncover consumers' needs and preferences. By utilising user preference surveys, market analysis data, and user feedback, the study reveals key insights into bionic furniture design. It was found that semiotics enhances the cultural depth and aesthetic value of designs by drawing on natural symbols, while semantics aids designers in better understanding users' cognitive and emotional responses, thus optimising the functionality and experience of bionic furniture. The results demonstrate that comfort, design style, and functional requirements in bionic furniture design are closely linked to consumers' purchase intentions. Through digital quantitative analysis, this study offers an innovative theoretical framework and practical guidance for future bionic furniture design, helping designers create products that align more closely with market demands.

Keywords. Digital Quantification, Bionic Furniture Design, Symbolic Design, Semantic Design

1. Introduction

Semiotics and semantics, as crucial theoretical tools for studying symbol systems and the generation of meaning, hold great potential in design, particularly in bionic design [1]. By interpreting and applying natural symbols, semiotics enables designers to create works with deeper cultural and emotional resonance [2]. Semantics, which examines the meaningful interactions between users and design objects, helps guide designers to better understand user needs, thus optimising functionality and enhancing the user experience [3].

Through digital quantitative research methods, designers can more accurately capture and analyse user preferences, market demands, and other relevant data, providing strong support for design decisions [4]. By integrating semiotic and semantic theory with digital quantitative research methods, innovative design solutions can be developed that better meet user needs in bionic furniture design.

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1.1. Research Questions and Objectives

The primary aim of this study is to explore the systematic application of semiotics and semantics in bionic furniture design, with the goal of enhancing the cultural depth, aesthetic value, and overall user experience. The key objective of this research is to propose an innovative approach to bionic furniture design by integrating semiotics and semantics with digital quantification research methods. This will provide a systematic theoretical framework and practical tools for designers. The findings aim to offer a fresh perspective on bionic furniture design, enabling designers to create products that embody cultural significance, aesthetic appeal, and user-centric functionality.

1.2. Research Innovation

This study represents a novel intersection of semiotics, semantics, and bionic design, which has been relatively underexplored in the context of bionic furniture. By combining theory and practice, it proposes an innovative design methodology. Whereas most previous design studies have relied primarily on qualitative analysis, this research introduces digital quantitative methods to gain a more precise understanding of user needs and market trends through big data analysis, thus providing solid data-driven support for design decisions. Additionally, by applying semiotics and semantics, this study not only focusses on the functional aspects of bionic furniture but also on enhancing its cultural significance and the emotional experience of users. This approach opens up a new developmental direction for bionic furniture design.

2. Literature Review

In this research, semiotics, semantics, bionic design, and digital quantification methods form the core theoretical foundation. These theories and approaches not only offer fresh perspectives and tools for innovation in bionic furniture design but also demonstrate their unique value and potential for practical application.

2.1. Semiotics and Design

Semiotics, the study of symbolic systems and meaning making, is rooted in the linguistic theories of Ferdinand de Saussure and the philosophical ideas of Charles Saunders Peirce [5]. Saussure introduced the relationship between the "signifier" (the form of a sign) and the "signified" (the concept it represents), emphasising the dual structure in which the signifier acts as the carrier of meaning. Designers use elements such as form, colour, and material not only to create functional objects but also to imbue them with cultural significance and emotional resonance. By employing semiotic principles, designers can craft products that go beyond functionality, creating deeper connections with users through symbolic representation [6].

2.2. Semantics and Design

Semantics is concerned with the meaning of language and symbolic systems, focusing on how meaning is generated and understood in context [7]. Key concepts in semantics

include lexical meaning, syntactic structure, context, and implied meaning. While semiotics emphasises the structure of signs, semantics is more focused on how meanings – particularly linguistic ones – are interpreted and conveyed[8]. In design, semantics plays a crucial role in how users interact with design objects. Design objects are more than just physical entities; they communicate through their form, material, and function, resonating with users' cognitive and emotional responses. By applying semantic principles, designers can predict and understand how users will interpret and engage with their designs, allowing them to optimise both functionality and user experience to meet expectations more effectively [9].

2.3. Bionic Furniture Design

Bionic design, which emerged in the early 20th century, draws inspiration from nature's forms, structures, and functions to apply them in human design and technological innovation[10]. The core principle of bionic design is to mimic the efficiency, sustainability, and intelligence of natural systems, aiming to create products and technologies that are more environmentally friendly and effective. In furniture design, bionic design takes cues from nature to develop furniture that is not only aesthetically pleasing but also functional [11]. This can involve mimicking natural forms, materials, and structural efficiencies. For example, furniture can be designed with lightweight, high-strength properties by emulating plant growth structures or incorporate surface materials with self-cleaning properties modelled after animal skins. The goal is to enhance both the appearance and the underlying structure and function of the furniture, creating pieces that offer both beauty and utility.

2.4. Digital Quantitative Research Methods

Digital quantification research is a data-driven approach that uncovers design patterns and user needs through statistical analysis and algorithmic models. Large-scale user research and behavioural data analysis can reveal latent user needs and preferences, providing designers with focused direction [12]. Market data and trend analysis models also help predict future design trends and consumer behaviours, forming a foundation for strategic design decisions. Additionally, quantitative evaluation of user experiences helps identify and rectify issues within the design, leading to improved user satisfaction and increased market competitiveness.

In the context of bionic furniture design, digital quantitative research methods allow designers to gauge user acceptance of bionic elements and understand how different design features influence user emotions and perception. By integrating digital quantitative research with semiotics and semantics, designers can create furniture that not only meets market demands but also maintains strong aesthetic and cultural values.

3. Research Method

This study aims to explore the application of semiotics and semantics in bionic furniture design through quantitative research. The research methodology consists of four key steps: research design, selection of research subjects, questionnaire design and implementation, and data processing.

3.1. Research Design

A research framework for bionic furniture design was constructed based on the theories of semiotics and semantics. The literature review provided the foundation for the study and helped define key variables and assumptions. Questionnaires were developed to gather data on user preferences and needs related to bionic furniture design, covering aspects such as users' perception, aesthetic preferences, and functional requirements. After collecting the questionnaire data, statistical methods such as descriptive statistics and multiple regression analysis were employed to uncover the relationship between user preferences and design elements.

To ensure the validity and representativeness of the data, the study selected consumers interested in furniture design and actual purchasing needs. The sample included participants from various age groups, genders, occupational backgrounds, and cultural contexts. A total of 498 valid questionnaires were collected, ensuring the reliability and scientific rigour of the data analysis.

3.2. Questionnaire Design and Implementation

This study utilised a questionnaire survey method, divided into four main sections. The first section collected basic demographic information about the respondents, such as gender, age, education, and income level. The second section assessed respondents' understanding and preferences regarding bionic furniture design, including evaluations of key design elements like form, material, and color. The third section focused on functional requirements, investigating respondents' needs and expectations concerning practicality, comfort, and functional diversity in bionic furniture. The questionnaire used a five-point Likert scale, with responses ranging from "strongly agree" to "strongly disagree," corresponding to scores of 5, 4, 3, 2, and 1, respectively. The specific questionnaire questions are detailed in Table 1 and Table 2.

Table 1. The questionnaire design for assessing perception and preferences regarding bionic furniture design

The questionnaire design for assessing perception and preferences regarding bionic furniture design
Q2-1: I am very familiar with bionic design.
Q2-2: I like the design style of bionic furniture.
Q2-3: Bionic design influences my furniture purchasing decisions.
Q2-4: I like the shape design of bionic furniture (e.g., mimicking the forms of animals or plants).
Q2-5: I appreciate the material design of bionic furniture (e.g., using natural or biomimetic materials).
Q2-6: I like the colour design of bionic furniture (e.g., incorporating natural tones).
Q2-7: I appreciate the functional design of bionic furniture (e.g., multi-functional features).
Q2-8: I enjoy the comfort of bionic furniture (e.g., in terms of seating or tactile experience).
Q2-9: I like the incorporation of natural elements (e.g., animals or plants) in bionic furniture.

Table 2. Questionnaire design for functional needs and expectations of bionic furniture design

Questionnaire design for functional needs and expectations of bionic furniture design
Q3-1: I am very satisfied with the performance of bionic furniture.
Q3-2: I believe bionic furniture provides a high level of comfort.
Q3-3: Bionic furniture makes me feel happy and joyful.
Q3-4: I find bionic furniture to be highly practical.
Q3-5: I think bionic furniture is aesthetically pleasing.
Q3-6: I believe bionic furniture offers me emotional comfort.
Q3-7: I prefer bionic furniture to be unique.
Q3-8: I feel safe and secure when using bionic furniture.
Q3-9: Bionic furniture meets my emotional needs.
Q3-10: If such a bionic furniture design exists, I would recommend it to friends and family.

4. Data Analysis and Results

4.1. Descriptive Statistics

In this study, 498 participants from various regions of China were surveyed. Descriptive statistics reveal that 36.75% of the participants were male, while 57.23% were female. In terms of age, the largest group was "20 to 30 years old," accounting for 68.88% of the participants, while the "over 60 years old" category had the lowest representation at 0.00%. Regarding educational background, "undergraduate" was the most common level of education, making up 53.21% of respondents, while "doctoral" was the least common, at 2.81%. In terms of income, the majority (69.08%) reported earning between 50,000 and 100,000 yuan annually, with only 7.03% earning more than 100,000 yuan.

4.2. Descriptive Statistics

The second section of the questionnaire focusses on participants' perception and preferences regarding bionic furniture design, including their opinions on aspects such as form, material, and colour, as detailed in Table 3. For question 2-8, "I like the comfort design of bionic furniture (e.g., the feeling of sitting and touching)," the average score was the highest at 4.03. In contrast, for question 2-6, "I like the colour design of bionic furniture (e.g., the use of natural colours)," the average score was the lowest at 2.84.

The third section of the questionnaire focusses on consumers' functional requirements and expectations for bionic furniture design, as shown in Table 4. Question 3-2, "I believe bionic furniture will provide a high level of comfort," had the highest mean value of 4.03. In contrast, question 3-5, "I find bionic furniture very beautiful," had the lowest mean value at 2.49.

Table 3. Descriptive statistics on consumers' perception and preferences regarding bionic furniture design

Question	N	Mean	Std. Deviation
Q2-1	498	3.24	1.192
Q2-2	498	3.79	1.262
Q2-3	498	3.78	1.181
Q2-4	498	3.08	1.243
Q2-5	498	3.00	1.200
Q2-6	498	2.84	1.332
Q2-7	498	3.07	1.233
Q2-8	498	4.03	1.167
Q2-9	498	3.81	1.154

Table 4. Descriptive statistics on functional requirements and expectations for bionic furniture design

Question	N	Mean	Std. Deviation
Q3-1	498	3.12	1.160
Q3-2	498	4.03	1.175
Q3-3	498	3.55	1.155
Q3-4	498	2.99	1.209
Q3-5	498	2.49	1.256
Q3-6	498	3.68	1.095
Q3-7	498	3.60	1.129
Q3-8	498	3.62	1.198
Q3-9	498	3.66	1.092
Q3-10	498	3.21	1.252

Based on the top three highest average scores from the second section of the questionnaire, a correlation analysis was conducted with the consumer expectations from the third section. The analysis utilised Pearson's chi-square test (X^2), degrees of freedom (*df*), and significance analysis (*p*) in SPSS software. Pearson's chi-square test examines the independence or association between two categorical variables by comparing the observed frequencies with the expected frequencies, determining if there is a statistically significant association between the variables. In this study, the test helps identify the

relationship between consumers' perception and preference for bionic furniture and their functional needs and expectations for its design.

Degrees of freedom represent the independent pieces of information in a statistical model that are used to calculate the test statistic. They indicate how much of the data can vary without impacting the model's outcomes, providing further clarity on the chi-square test results and ensuring the conclusions' reliability and validity.

Significance analysis calculates *p*-values to determine whether the statistical results are significant. The p-value reflects the probability of observing the given result (or a more extreme one) if the null hypothesis is true. Generally, a *p*-value of less than 0.05 ($p < 0.05$) indicates a significant association.

As shown in Table 5, the chi-square statistics for most of the questions reveal a high level of significance ($p < 0.05$), indicating a significant association between "perception and preference for bionic furniture design features (comfort, Q2-8)" and "consumer functional requirements and expectations for bionic furniture design." This suggests that the comfort aspect of bionic furniture design has a significant influence on consumers' functional needs and expectations.

As shown in Table 6, the chi-square test results for "consumer perception and preference for bionic furniture design features (design style, Q2-2)" and "functional requirements and expectations for bionic furniture design (Q3-1 to Q3-10)" indicate that all chi-square statistics were statistically significant ($p < 0.05$). This suggests that the "design style" aspect of bionic furniture has a significant impact on consumers' functional needs and expectations. Therefore, when designing bionic furniture, the choice of design style plays a crucial role in enhancing consumer satisfaction and purchase intention.

Table 5. Analysis of the correlation between consumers' perception and preference (comfort) for bionic furniture design characteristics and their functional requirements and expectations for bionic furniture design.

Question	X^2	*df*	*p*
Q3-1	.289	4	.000
Q3-2	.255	4	.000
Q3-3	.310	4	.000
Q3-4	.293	4	.000
Q3-5	.244	4	.000
Q3-6	.255	4	.000
Q3-7	.234	4	.000
Q3-8	.197	4	.000
Q3-9	.224	4	.000
Q3-10	.125	4	.005

Table 6. Correlation analysis between consumer perception and preference (design style) for bionic furniture design features and functional requirements and expectations for bionic furniture design.

Question	X^2	*df*	*p*
Q3-1	.193	4	.000
Q3-2	.212	4	.000
Q3-3	.294	4	.000
Q3-4	.170	4	.000
Q3-5	.120	4	.001
Q3-6	.283	4	.000
Q3-7	.305	4	.000
Q3-8	.255	4	.000
Q3-9	.224	4	.000
Q3-10	.178	4	.000

As shown in Table 7, the chi-square test results for "Consumers' perception and preference for bionic furniture design features (influence on purchase, Q2-3)" and "functional requirements and expectations for bionic furniture design (Q3-1 to Q3-10)" reveal that all chi-square statistics were statistically significant ($p < 0.05$). This indicates that the bionic design of furniture significantly influences consumers' functional requirements and expectations. Moreover, bionic design impacts consumers' purchasing decisions. Therefore, when designing furniture, incorporating bionic elements is an important guiding factor, and designers should focus on this aspect to enhance consumer satisfaction and overall user experience.

Table 7. Correlation analysis of "bionic furniture design characteristics (influence on purchase)" and "functional requirements and expectations for bionic furniture design."

Question	X^2	*df*	*p*
Q3-1	.156	4	.000
Q3-2	.233	4	.000
Q3-3	.267	4	.000
Q3-4	.137	4	.002
Q3-5	.113	4	.001
Q3-6	.321	4	.000
Q3-7	.258	4	.000
Q3-8	.232	4	.000
Q3-9	.228	4	.000
Q3-10	.154	4	.001

4.3. Linear Regression Analysis

The primary goal of linear regression is to identify which factors significantly influence consumer expectations, providing valuable insights for product design. The results help researchers understand and explain how consumer perceptions and preferences affect their expectations.

The model summary (Table 8) shows that, although the R-squared values are relatively low (all below 0.2), the influence of all independent variables on consumer expectations is statistically significant. This suggests that these variables can explain consumer expectations for bionic furniture design to some extent. The significance tests (p-values) in the ANOVA table (Table 9) and the coefficients table (Table 10) are all below 0.05, indicating that the variables of comfort, design style, and influence on purchase have a significant impact on consumer expectations. The scatter plot in Figure 1 demonstrates a positive relationship between consumer perceptions and preferences and consumer expectations, further validating the regression model.

Table 8. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Comfort	.1826[a]	.0405	.0385	1.1499
Design Style	.2134[a]	.0517	.0497	1.1431
Influence on Purchase	.1999[a]	.0467	.0449	1.1461
a. Predictors: Comfort, Design Style, Influence on Purchase				

Table 9. ANOVA[a]

Model		Sum of Squares	*df*	Mean Square	F	Sig.
Comfort	Regression	26.435	1	26.4357	21.3667	.0413[b]
	Residual	658.058	496	1.3266		
	Total	684.493	497			
Design Style	Regression	34.1816	1	34.1816	27.5357	.005[b]
	Residual	650.3118	496	1.3112		
	Total	684.4934	497			
Influence on Purchase	Regression	30.5661	1	30.5661	24.8195	.0079[b]
	Residual	653.9274	496	1.3183		
	Total	684.4935	497			
a. Dependent Variable: Consumer Expectations						
b. Predictors: Comfort, Design Style, Influence on Purchase						

Table 10. Coefficients[a] (a. Dependent Variable: Consumer Expectations)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.673	.173		15.527	.000

Comfort	.1712	.0441	1738	3.9843	.0413
Design Style	.1957	.0405	2134	4.9076	.005
Influence on Purchase	.1953	.0434	1999	4.5867	.0079

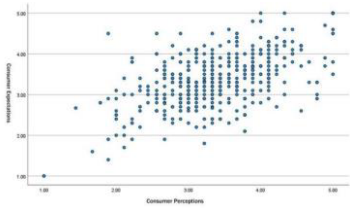

Figure 1. Scatter plot of consumer expectations against consumer perceptions.

5. Results Discussion

Based on the analysis of data from 498 respondents, the results show that consumers have varying preferences for different design elements of bionic furniture. Comfort, such as the sitting and tactile experience, received the highest evaluation, with an average score of 4.03. This indicates that consumers place a high value on the comfort of furniture, aligning with the core principle of biomimetic design, which aims to optimise the user experience by mimicking natural forms and functions. However, colour design received the lowest recognition, with an average score of 2.84. This suggests that the use of natural colours may not fully satisfy the aesthetic preferences of modern consumers. Designers may need to strike a balance between traditional natural elements and contemporary fashion colours to better appeal to consumer tastes.

In terms of functional requirements, comfort remains the top priority, with an average score of 4.03, reaffirming the critical role of comfort in bionic furniture design. On the other hand, aesthetics received a lower score of 2.49, indicating that there is room for improvement in the visual appeal of bionic furniture currently available. This may be due to the fact that some designs prioritise functionality over visual aesthetics. Additionally, consumers rated safety, uniqueness, and emotional needs highly, showing that they not only expect practical functionality but also psychological comfort from bionic furniture. This suggests that future designs should emphasise emotional engagement, utilising bionic elements to create a deeper emotional connection with users.

The data analysis in this study demonstrates the significant impact of semiotics and semantics in bionic furniture design. The chi-square test results indicate a statistically significant relationship between the comfort and design style in bionic furniture and consumers' functional needs and expectations. This suggests that the cultural and emotional messages conveyed through natural forms and symbols have a direct influence on consumer preferences. For instance, consumers showed a high level of acceptance for natural elements in bionic furniture, such as designs imitating the forms of animals and plants (Q2-9, with an average score of 3.81). This validates the importance of semiotics in bionic design, where natural symbols enhance the cultural and aesthetic value of furniture by conveying specific cultural and emotional meanings.

6. Research Value and Insights

By integrating semiotics and semantics into bionic furniture design and applying digital quantitative research methods, this study underscores the pivotal role of bionic design in meeting user needs and enhancing cultural connotation and aesthetic value. The use of digital quantification provides robust data to support design decisions by revealing consumer preferences for bionic furniture.

Through linear regression analysis, the study identified comfort, design style, and purchase influence as key factors affecting consumer expectations for bionic furniture design, with statistically significant relationships between these factors. This suggests that combining semiotics, semantics, and digital analysis enables designers to better address consumers' functional needs while enhancing the market competitiveness of products.

The findings suggest that future bionic furniture design should further explore comfort and emotional resonance, using semiotics and semantics to better understand and incorporate natural symbols, creating designs with rich cultural meaning and visual appeal. Additionally, colour and aesthetic choices should align with modern trends to increase consumers' desire to purchase. By continuously refining symbolic communication and emotional feedback in the design process, bionic furniture will have greater market potential and user appeal.

In conclusion, this study provides a new perspective on bionic furniture design by combining semiotics, semantics, and digital quantification methods, laying a strong foundation for future developments in the field.

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