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A Study on Optimization Design of User Experience of Interface Icon of Science Popularization App for School-age Children Based on Logistic Regression Analysis

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Abstracts: In this study, logistic regression analysis, orthogonal experimental design, user experience evaluation, and A/B testing are used to explore the key design factors of children's app icons and make suggestions for optimization. Firstly, user information is collected through a questionnaire survey, and the core elements affecting users' adoption willingness are analyzed by logistic regression. Second, orthogonal experimental design is used to evaluate the influence of function combinations on users' preferences and screen the optimal function configuration. Once again, the user experience method is used to collect feedback on actual use, evaluate usability, ease of use, and satisfaction, and propose improvement measures. Finally, the A/B test verifies the effectiveness of the optimization scheme. Taking children's science apps as the research object, the results show that the methodological framework proposed in this study significantly improves user experience and provides designers with a way to accurately understand children's preferences and needs and develop high-quality science apps.

Keywords: Popular science app; Ordinal logistic regression analysis; School-age children; Interface icon design

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1. Introduction

With the rapid development of mobile Internet technology, children's apps are developing rapidly, but children's science apps are relatively lagging in development, failing to start from children's cognitive needs, and the user positioning is not clear. This imprecise positioning leads to a variety of problems that may occur during the use by children, affecting the use of experience and interest in learning. Although there have been extensive studies on the

interface design of apps for school-age children, the icon design is still insufficient. As a key element, icons have a direct impact on children's user perception and interaction. Current research mostly focuses on a single design factor, ignoring the complex interactions between multidimensional variables. Given this, this study adopts logistic regression analysis to construct a relationship model between user experience and design patterns, systematically explores optimization strategies, accurately identifies and verifies the key factors affecting the user experience of children's app interface icons in science popularization, and puts forward design optimization suggestions based on scientific evidence.

2. Research methodology

User experience is crucial in mobile app design, covering the whole process of user interaction with hardware and software. Norman divided it into instinctive, behavioral, and reflective layers, which helps designers to deeply understand user needs [1]. Cao analyzed the user interaction needs and design of smartphones [2]. Based on Park's experience framework (behavior, perception, emotion), this study aims to construct a user experience evaluation system for mobile apps for children, to comprehensively assess the user's feelings and satisfaction, and to provide a scientific basis for improving the design.

Logistic regression analysis is a generalized nonlinear model, commonly used in data mining, disease diagnosis, economic forecasting, and other fields [3]. It can effectively model the relationship between categorical dependent and independent variables and quantify the contribution of independent variables to the probability of category attribution. Suriya K assessed souvenir design preferences of international tourists in northern Thailand using binary logistic regression and proposing design strategies [4]. Park and Lee applied logistic regression to optimize the layout of a website to improve user engagement on an e-commerce platform [5]. Chen and Li used logistic regression to explore the impact of graphical elements on user satisfaction of digital advertisements [6]. Given its wide application in design research, this study focuses on optimizing user experience design with logistic regression, especially selecting an ordinal logistic regression model to deal with the interaction effects of ordered multicategorical variables and independent variables to provide data support for precise optimization strategies.

Cui used orthogonal experimental methods to study fiber properties Conditions for obtaining a predetermined diameter and morphology of electroscope fibers [7]. In the development of a science app for school-age children, it provides the basis for multi-dimensional user experience optimization. Derived from mathematical statistics, it arranges experiments through orthogonal tables to reduce interaction effects. Compared with comprehensive design, orthogonal design reduces cost and improves efficiency. Science app user experience involves interface, interaction, content, and feedback. Orthogonal design can study these dimensions and make optimization suggestions. An orthogonal design of experiments approach combined with quantitative analysis of small angle X-ray scattering (SAXS) patterns was used to optimize the synthesis of bioactive glasses with highly ordered mesoporous structures (MBG) [8]. An improved SOM based on the orthogonal design of the experiments technique is proposed to obtain the optimal solution [9]. The combination of orthogonal design and logistic regression in the design of a science app for school-age children can more accurately quantify the contribution of factors to the user experience.

3. Research framework

In the study of optimizing the icon experience of the science children's app, the team used sequential logistic

regression analysis (**Figure 1**). Establishing the design model and constructing samples to establish the evaluation system, so the user experience is explored in depth. The model reveals the design-experience association, determines the optimal solution, and verifies the effect through iteration, A/B testing, and large-scale user testing.

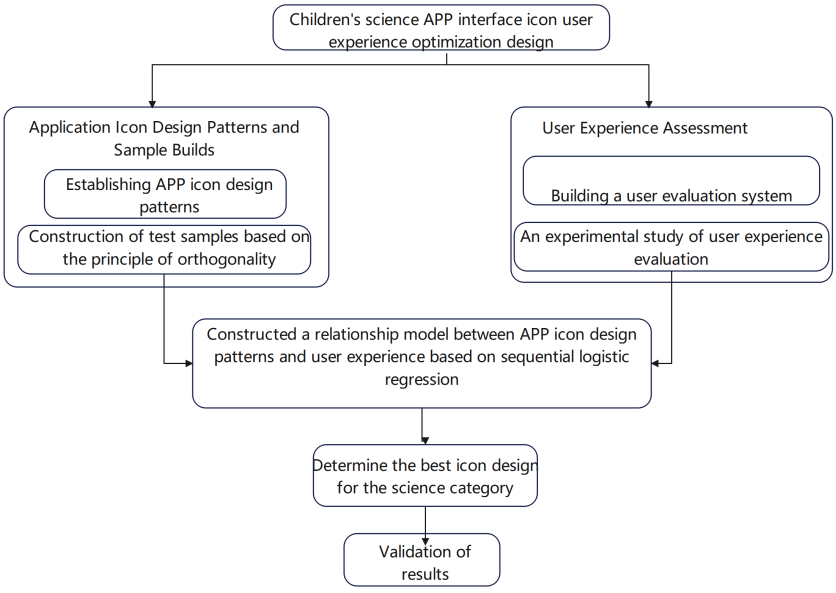

Figure 1. Research method framework

4. Research process

4.1. Establishing a pattern of interface icon design for children's science apps

Referring to the studies and the market children's app icon design, this study used the focus group method to determine the design pattern (see **Table 1** for details), which is divided into five parts, with 2–4 types in each part, which is denoted by Xij (i is the kind, j is the specific type) [9–15]. Icon color (X1) contains: single tone (X11), similar tone (X12), and contrasting tone (X13).

Table 1. Design patterns of outdoor tourism mobile apps

Design Patterns	Type I	Type II	Type III	Type IV
Icon color (X1)	Complementary color (X11)	Neighboring colors (X12)	Contrasting colors (X13)	Unicolor (X14)
Icon shape (X2)	Faceted (X21)	Linear (X22)	Line and surface blending (X23)	
Icon form (X3)	Dynamic (X31)	Static (X32)		
Icon border (X4)	Circle (X41)	Rounded square (X42)	Triangles (X43)	Rhombus (X44)
Icon style (X5)	Character (X51)	Artifact (X52)	Symbols (X53)	

4.2. Constructing an experimental sample of children's science app interface icons based on the orthogonality principle

The numerous design options in **Table 1** make full recovery impractical. Therefore, orthogonal tables are commonly used for assessment, such as the L20 method, which streamlines 288 scenarios into 16. The number of rows of the orthogonal table is the sample size, the number of columns represents the factors, and the numbers in

the columns represent the different levels of the factors (**Table 2**).

Table 2. Sample combination scheme for outdoor travel mobile app based on L32 (36*42) orthogonal array

Sample number	Icon colors	Icon shape	Icon forms	Icon border	Icon style
1	Complementary colors	Faceted	Dynamic	Rounded	Characters
2	Complementary colors	Linear	Static	Rounded square	Artifacts
3	Complementary colors	Mixed linear and surface	Dynamic	Triangle	Symbols
4	Complementary colors	Faceted	Static	Rhombus	Characters
5	Neighboring colors	Linear	Dynamic	Round	Artifacts
6	Neighboring colors	Linear	Static	Rounded square	Symbol
7	Neighboring colors	Surface	Dynamic	Triangular	Characters
8	Neighboring colors	Linear	Static	Rhombus	Artifacts
9	Contrasting colors	Linear	Dynamic	Round	Symbol
10	Contrasting colors	Surface	Static	Rounded square	Characters
11	Contrasting colors	Linear	Dynamic	Triangular	Artifacts
12	Contrasting colors	Linear	Static	Rhombus	Symbol
13	Uniform Color	Surface	Dynamic	Round	Characters
14	Uniform Color	Linear	Static	Rounded square	Artifacts
15	Uniform Color	Linear	Dynamic	Triangular	Symbol
16	Uniform colors	Surface	Static	Rhombus	Characters
17	Complementary colors	Linear	Dynamic	Rounded square	Symbol
18	Contrasting colors	Faceted	Dynamic	Round	Artifacts
19	Neighboring colors	Linear	Dynamic	Round	Role
20	Uniform colors	Linear mixing	Static	Rhombus	Role

5. Children's science popularization app interface icon user experience evaluation

5.1. Constructing a user evaluation system for children's science app interface icons

Based on the evaluation system of Park and integrating children's physiological and psychological characteristics, the interface icons of children's science apps in the current market were analyzed in depth as shown in the figure, and a comprehensive evaluation system of mobile children's apps for child enthusiasts was constructed. This system covers three core dimensions: behavioral experience (Dimension A), perceptual experience (Dimension B), and emotional experience (Dimension C), with a total of 18 specific evaluation indexes subdivided under each dimension, which are shown in **Figure 2**. For cell phone users' feedback, a questionnaire containing nineteen issues closely related to the user experience was designed, and a 7-order Likert scale was used for scoring. Cronbach's score of the questionnaire was found to be very high, as the Cronbach's coefficient of the questionnaire is 0.907, showing a very high internal consistency and ensuring the reliability of the questionnaire data.

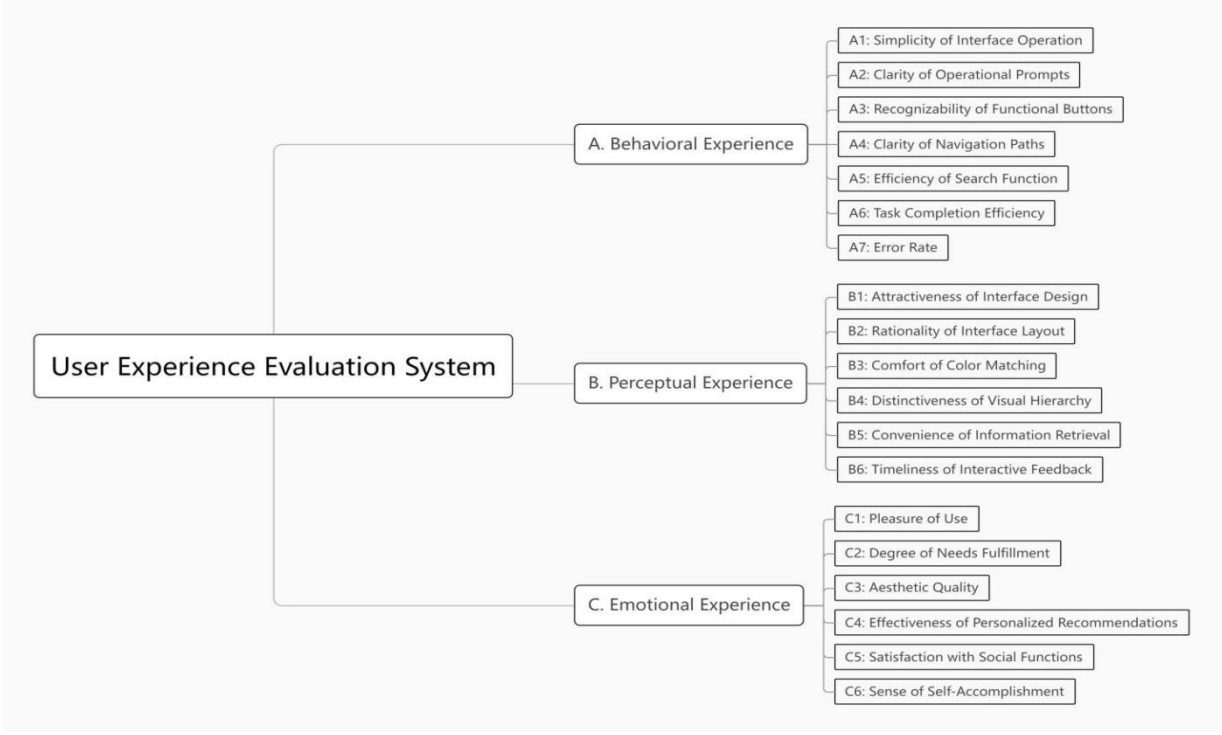

Figure 2. User experience evaluation system for outdoor tourism mobile app

5.2. Experiment with the user experience of children's science popularization app interface icon

In the user experience trial, the study selected 30 children (16 males and 14 females) who were proficient in cell phone operation and had more than 3 years of experience in using children's apps. The trial assessed the perceptual experience first, and then participants were asked to perform tasks to measure behavioral experience, such as icon recognition. The full duration was 45–60 minutes to ensure concentration. Finally, participants comprehensively evaluated the interface icons, and we collected ratings and calculated the mean as the results (**Table 3**).

Table 3. Mean user experience evaluation scores of samples obtained from orthogonal experiment

Serial number	A Behavioral experience						B Perceptual experience						C Emotional experience						Mean value
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	
1	3.75	3.78	3.95	3.64	3.32	3.24	3.01	3.05	4.00	4.07	3.05	5.20	5.50	1.73	2.00	3.12	2.56	3.89	3.49
2	4.23	2.56	3.24	5.13	3.12	3.54	3.64	3.78	4.23	4.21	3.24	2.01	5.21	4.21	4.32	5.23	1.27	2.43	3.64
3	2.93	4.32	5.12	4.31	4.02	4.36	4.54	4.31	3.68	3.98	3.75	2.01	2.54	3.68	2.07	3.54	1.98	2.34	3.52
4	5.17	4.16	4.35	4.98	3.68	3.78	3.65	3.45	2.01	5.04	5.32	4.02	3.57	3.98	4.56	5.12	3.45	3.62	4.1
5	4.41	3.87	2.05	4.05	4.36	5.08	4.23	4.36	4.12	3.87	3.54	3.65	3.45	2.56	4.32	5.26	5.45	3.12	3.98
6	3.65	3.45	3.45	3.21	2.04	5.12	4.36	2.36	3.01	3.45	3.06	3.85	3.64	4.36	4.98	5.21	4.36	5.23	3.82
7	1.24	2.05	1.68	2.36	1.56	1.98	2.32	2.25	3.65	4.32	4.12	5.12	4.69	3.99	4.12	5.01	4.36	4.78	3.31
8	4.32	5.23	4.63	2.35	3.36	3.45	3.69	4.89	4.68	4.32	3.59	3.68	3.45	4.01	4.25	4.36	4.58	5.27	4.11
9	5.36	2.32	4.36	4.03	4.35	2.30	1.56	2.67	3.65	3.25	4.26	3.65	2.34	2.65	3.87	3.65	4.24	3.25	4.33

Table 1 (Continued)

Serial number	A Behavioral experience						B Perceptual experience						C Emotional experience						Mean value
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	
10	3.24	2.36	2.36	4.36	5.21	4.36	4.36	3.23	4.36	3.25	4.36	4.23	3.23	4.36	5.32	3.24	4.36	5.31	3.97
11	3.24	5.32	4.32	3.69	3.89	3.65	3.24	2.21	2.34	4.25	4.36	4.36	4.32	5.12	5.36	5.15	5.46	5.68	4.22
12	3.12	3.56	4.32	4.36	4.65	4.35	2.35	3.56	4.36	5.36	2.34	2.65	3.54	4.36	3.54	3.24	4.36	3.56	3.75
13	2.32	4.35	3.54	3.64	3.24	4.65	3.24	3.65	3.54	3.86	3.77	4.36	5.45	3.64	4.35	4.65	4.89	4.67	3.98
14	3.45	3.65	3.45	3.23	3.56	4.21	4.32	3.98	3.78	3.65	2.13	3.13	2.36	4.31	3.89	3.78	3.98	4.15	3.61
15	3.65	3.89	3.65	3.78	3.68	3.69	3.78	2.12	2.54	1.23	4.56	4.65	4.32	4.35	4.12	2.15	1.38	2.37	3.32
16	4.2	3.56	3.23	3.36	3.45	3.65	4.23	4.65	4.85	4.36	4.65	4.32	5.36	4.32	5.21	2.13	1.23	1.65	3.80
17	2.65	1.36	5.32	4.36	2.31	3.36	2.35	5.12	4.35	2.36	4.35	5.21	2.31	3.56	3.54	3.78	3.54	3.12	3.49
18	4.23	4.32	4.56	4.78	4.36	4.21	4.98	4.36	4.56	1.23	1.36	1.35	3.56	2.35	4.35	3.32	2.65	3.89	3.57
19	5.32	4.36	2.31	3.15	2.34	2.13	2.15	2.36	3.54	3.45	4.26	4.55	4.65	4.32	4.89	4.87	2.31	3.22	5.84
20	5.52	3.15	2.32	5.32	4.36	3.65	2.45	4.36	3.65	3.78	3.98	4.12	5.12	3.68	3.78	4.21	4.69	5.23	4.07

5.3. Conducting a user experience trial of interface icons of a science app on children

This study focuses on how children's science app interface icon design patterns affect user experience. The study applied a sequential logistic regression model and analyzed the data with the help of SPSS 22.0 software, aiming to discover design patterns that can enhance user experience. The detailed results are shown in **Table 4**.

Table 4. Results of ordinal logistic regression analysis

Regression coefficient			Regression coefficient		
value of a queue (math.)	[y satisfaction=1]	-	placement	[X2 Icon Shape=X22 Linear]	0.1
	[y satisfaction=1]			[X2 Icon Shape=X23 Linear Blend]	0.212
	[y Satisfaction=2]			[X3 Icon Shape=X31 Dynamic]	1.451
	[y Satisfaction=3]			[X3 Icon Shape=X32 Static]	0
	[y Satisfaction=4]			[X4 Icon Border=X41 Round]	0
	[y satisfaction=5]			[X4 Icon Border=X42 Rounded Square]	1.345
placement	[X1 Icon Color = X11 Complementary]	-0.124		[X4 Icon Border=X43 Triangle]	-0.214
	[X1 Icon Color = X12 Adjacent Color]	0.135		[X4 Icon Border=X44 Rhombus]	0.123
	[X1 Icon Color = X13 contrasting color]	-0.216		[X5 Icon Style=X51 Character]	0
	[X1 Icon Color = X14 Unity Color]	1.325		[X5 Icon Style=X52 Artifact]	1.339
	[X2 Icon Shape = X21 Faceted]	0.101		[X5 Icon Style=X53 Symbol]	1.439

5.4. Determine the optimal solution for children's science app interface icons

According to the above results, the optimal design combination scheme for the interface icon design of the popular science children's app is X11, X21, X31, X42, and X53, and the icon color is the same color when the icon style is the symbol style, the icon shape style is the face style, the icon form style is the dynamic style, and the icon border

style is the rounded square.

Using equations (1)–(3), the study can find λ1=0, λ2 =0, λ3=0.004, λ4 =0.025, λ5=0.121, and at this time, P y(=1)=0, P y(=3)=0.004, P y(=4)=0.021, P y(=5)=0.096, and P y(=6)=0.879. The results show that the probability is maximum when the satisfaction level is 6 and the user experience is evaluated as satisfactory.

Icon design features of the optimal children's science app are as follows. Icon style: adopting clear and easy-to-understand symbols, simplifying navigation, reducing children's cognitive burden, and improving usability. Icon shape: Combine lines and surface design to maintain visual interest, avoid complexity, and enhance aesthetics. Icon form: incorporate dynamic elements to attract children's attention, reinforce learning, and provide visual cues. Icon Border: Use rounded square corners to balance simplicity and clarity, friendly and easy to understand. Icon Color: Use complementary colors to enhance visual distinction, improve recognition, and support children's visual processing.

Figure 3. Original design part interface display

Figure 4. Optimal design icon design interface display

6. Validation of sequential logistic regression results

Finally, the optimal design derived from regression analysis was identified in the L20 orthogonal table, and further experimental validation was subsequently conducted. The study reconvened the previous 30 participants and evaluated the user experience of the optimal design against the original design using A/B testing based on the established user experience evaluation system, and the results are summarized in **Table 5**. A *t*-test analysis of the results shows that there is a statistically significant difference in user experience between the optimal design and the original design ($P < 0.05$) and that the optimal design scores significantly higher than the original design. This finding supports our view that the use of logistic regression-based research methodology can effectively guide the research on optimal design of user experience.

Table 5. User experience evaluation scores for the best design and existing designs

	A. Behavioral experience							B. Perceptual experience						C. Emotional experience					
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Optimal design	6.05	5.85	6.03	5.94	6.05	6.54	5.68	5.95	6.23	6.54	5.78	5.46	6.23	6.85	5.98	6.03	6.12	5.45	5.63
Original design	2.03	1.76	3.02	2.60	2.00	1.36	2.65	3.04	2.65	3.65	2.01	3.05	2.58	3.54	3.32	2.58	2.14	2.36	1.04

7. Concluding remarks

Based on logistic regression and orthogonal experience tests, this study proposes an optimal design solution for symbol styles, dynamic icons, rounded corners with each other, and complementary color combinations, which can significantly enhance school-age children users. This study not only provides scientific design guidance for children's science communication applications but also provides a reference for optimizing the design of other children's applications through rigorous analysis and simulation methods. This study demonstrates that optimizing multidimensional design in conjunction with logistic regression data-based analysis methods can effectively improve children's user experience, enhance the educational value and attractiveness of the application, and provide an important reference path for the development and design of children's digital education products. In the future, it is recommended to continue exploring the effect of multifactor interaction to further optimize children's user interface experience.

Disclosure statement

The authors declare no conflict of interest.

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