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Evaluation of a Smart Audio System Based on the ViP Principle and the Analytic Hierarchy Process Human–Computer Interaction Design

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Abstract: The current limitations of user–product interaction with smart speakers have spurred the proposal of a model to circumvent these challenges. We used the ViP design principle to redefine the user's approach to interacting with the product. Throughout the deconstruction and design stages, we explored the structure and function of the conventional product across three layers: the product layer, interaction layer, and context layer using three models. We used the hierarchical analysis method to effectively quantify the design factors affecting user experience and identify the key design factors. This approach enabled us to contextualize the smart audio system, explore the interaction dynamics between the product and the user, and provide valuable insights on designing new products. A questionnaire method was used to survey 67 users, and a reliability test was conducted to ensure the validity of the questionnaire v (Cronbach's coefficient $\alpha = 0.868$). A pairwise comparison of factors was conducted on a 1–9 scale, with weights determined through the analytic hierarchy process (AHP). The combination of the ViP design principle and hierarchical analysis presents a novel and objective paradigm to guide designers to customize product characteristics (design attributes) to enhance user human–computer interaction experience. We validated the feasibility of the innovative design approach using the smart speaker model, offering insights for research on designing similar products.

Keywords: product design; smart speaker; ViP product design principles; hierarchical analysis method; user experience

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1. Introduction

The rapid advancement of technology, particularly with the emergence of the 5G era, artificial intelligence, and the Internet of Things, has led to the widespread integration of smart speakers into daily life. Despite their increasing prevalence, current smart speaker interactions often fall short of delivering optimal user experiences. Enhancing user experience is crucial not only for driving product innovation but also for improving product competitiveness [1]. Conventional smart products have shortcomings, such as limited usability and low levels of intelligence. Therefore, it is essential to prioritize the natural interaction of the user during use to enhance the user experience [2]. Previous theoretical research on smart speakers has primarily focused on active interactive services and the modeling of single-product designs, neglecting the development of innovative design methods based on the product–interaction–context system.

In response to these challenges, this paper proposes an innovative design method that combines the Value-in-Place (ViP) principle and analytic hierarchy process (AHP). This method offers a rational approach to help designers enrich their intuition and investigate, select, classify, and prioritize design elements. Designers can utilize ViP principles to analyze novel design strategies and incorporate the AHP to explore user demands for future products and select key design factors. This approach assists designers in gradually establishing a "contextual world", identifying entry points for design improvement, and developing innovative and valuable design schemes for smart speakers, thereby enhancing user experience. The combination of the ViP design principle and hierarchical analysis offers a novel paradigm for customizing product traits to enhance human–computer interaction experiences. This approach enables us to explore the interaction dynamics between products and humans, providing valuable insights for designing new products.

2. Related Work

Several scholars have conducted research on the human–computer interaction design of smart speakers. For instance, Wang Erzhuo et al. [3] explored how user attributes influence the preference for intelligent conversational agents using the Wizard of Oz method. Moreover, Zhao et al. [4] assessed the user satisfaction level after the smart speaker initiated the active interaction services using the Wizard of Oz method. Chen et al. [5] enhanced the appearance design of the smart speaker based on the extension theory. Wu et al. [6] proposed design principles for mini smart speakers, including "shape", "function", and "spirit", based on market analysis and component functionality.

Some scholars recently incorporated the ViP principle and the AHP into the product design process to enhance the human–computer interaction experience. For example, Kim et al. [7] developed future rehabilitation scenarios and rehabilitation design strategies according to the vision level, interaction level, and product level of the ViP design principle and validated the approach using a case study method. Souza [8] applied the ViP design principles to design social assistance robots. The ViP design is an interaction-based and context-driven design approach that aligns with the concept of natural interaction, aiming to explore design innovation and effectively improve user experience [9]. However, the qualitative classification method of the VIP principle poses challenges in accurately determining the priority of factors influencing user experience. Jeon et al. [10] used the AHP to establish an evaluation index hierarchy system for children's education devices and validated it through the fuzzy comprehensive evaluation approach. Molina et al. [11] improved the conventional NASA-TLX scale using the AHP and used physiological signals to validate its scientific auxiliary function. Cagiltay et al. [12] used the AHP to enhance the accuracy and applicability of decision making in RV design. The AHP rationalizes the complex qualitative evaluation process but has limitations related to user experience factors.

In the field of product design, incorporating ViP principles and the AHP has been an ongoing effort to enhance the human–computer interaction experience [7]. Recent developments have focused on refining these methods to better align with user needs and preferences. Initially, researchers explored the application of ViP design principles to various products, such as rehabilitation scenarios and social assistance robots [8]. However, the qualitative classification method of ViP presents challenges in accurately determining the priority of factors influencing user experience [9]. To address this limitation, researchers have turned to the AHP as a means of constructing hierarchical evaluation systems for different products, including children's education devices and RV design [10]. This approach rationalizes the complex qualitative evaluation process and allows for more accurate decision making [11]. Despite these advancements, there are still limitations in incorporating user experience factors in the AHP method [12]. Nevertheless, the continued efforts to refine these techniques illustrate the importance of prioritizing human–computer interaction in product design.

In summary, although previous research has made significant advances in applying ViP and AHP principles to product design, there are still aspects that require further exploration. One such aspect is the need for a comprehensive approach that effectively integrates ViP and the AHP, offering designers a rational framework to enhance their intuition and investigate, select, classify, and prioritize design factors. This gap in the current research landscape has inspired our proposed innovative design method, which combines ViP and the AHP to offer a systematic approach for analyzing design strategies and understanding user demands for future products. The purpose of our method is to guide designers in establishing a "contextual world" that serves as a foundation for improving and innovating smart speaker design by leveraging ViP principles to analyze novel design strategies and integrating the AHP to explore and prioritize key design factors based on user preferences. Ultimately, our approach strives to contribute to the development of more valuable and user-tailored design schemes, thereby enhancing the overall user experience of smart audio systems.

3. Construction of a Model based on the ViP Principle and the AHP

3.1. ViP Principle

Vision in Product Design (ViP) is a design framework established by Matthijs van Dijk and Paul Hekkert in the mid-1990s [13]. It is a context-driven approach that facilitates the interaction of various components, ensuring that designers align with future design considerations and providing insight into what to design and the underlying reasons for those designs. This framework provides a basis for designing the relationship between different components, indicating the motivation behind the development of these designs [14]. The ViP design approach provides a variety of design methods to assist designers in meticulously defining these goals and translating them into every aspect of the design concept. The most important part of the design is to establish a reference framework for the development of new products. The ViP design process is classified into two stages: "deconstruction" and "design" (as shown in Figure 1). The first stage involves deconstructing the three-layer model of the current product and exploring the significance of the existing product, including the appearance of the product, the interaction with people, and the broader context.

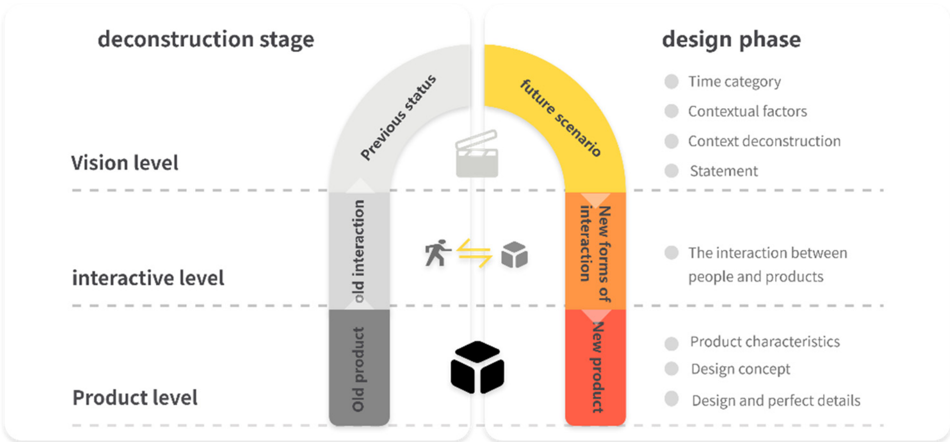

Figure 1. A flowchart showing the conventional ViP design process.

In recent years, the rapid growth of smart audio devices has been driven by the increasing demand for intelligent voice assistants and personalized audio experiences. Consequently, there has been a surge in research studies aimed at enhancing the interaction quality and user experience of these devices.

An essential aspect of this research is the product–interaction–context layers, which are integral to the ViP design principle. Deconstructing these layers allows for the identification of future user experience factors, providing designers with invaluable insights into how users interact with these devices. However, the challenge lies in quantifying and prioritizing these factors to ensure flexibility and accuracy.

The analytic hierarchy process (AHP) plays a crucial role in circumventing this challenge. Design metrics can be quantified by incorporating the AHP during the deconstruction phase, and factors can be prioritized based on user demands. This enhances the applicability and accuracy of the product design scheme, ensuring that it meets user expectations and provides a seamless and enjoyable experience.

Furthermore, the integration of the AHP allows designers to consider multiple factors simultaneously, such as cost, usability, and aesthetics when making design decisions. This holistic approach ensures that the final product is not only functional but also visually appealing and affordable.

3.2. Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) was proposed by the American operations research scientist Saaty in the early 1970s [15]. It is a decision analysis method that uses hierarchical weighting. The significance of indicators in the hierarchy is assessed using values ranging from 1 to 9 based on the scaling principle of the AHP, with their reciprocals serving as satisfaction values. The higher the satisfaction value, the more significant the indicator. The weights of design factors are determined using the analytic hierarchy process as outlined below [16]:

(1) Formulating a judgment matrix for the indicator layer A is performed as follows:

$$\boldsymbol{A} = (a_{ij})_{n \times n} \tag{1}$$

where a_{ij} represents the significance of i compared to indicator j.

$$a_{ij} > 0 \text{ and } a_{ij} = \frac{1}{a_{ji}}(i,\ j = 1,\ 2,\ \ldots,\ n) \tag{2}$$

(2) Solving the maximum eigenvalue using the consistency test is performed as follows:

$$CI = \frac{\lambda\text{max} - n}{n - 1} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

In the equation, λ_{max} represents the maximum eigenvalue of the judgment matrix. RI represents the random average consistency index (as shown in Table 1).

Table 1. Random mean consistency indicators.

N	1	2	3	4
RI	0	0	0.52	0.89

When CR < 0.10, the consistency of the judgment matrix is considered acceptable; otherwise, the judgment matrix should be modified appropriately.

(3) The robustness of the data is determined using three different calculation methods based on Equations (5)–(7), and the three results are summed and averaged ω_4 as follows:

$$\boldsymbol{AW} = \lambda_{\text{max}} \boldsymbol{W} \tag{5}$$

In the equation above, the eigenvector method is used, and w represents the weight vector.

(4) The calculation of the weight vector using the geometric average method is performed as follows:

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}},\ i = 1,\ 2,\ \ldots,\ n \tag{6}$$

(5) The calculation of the weight vector using the arithmetic mean method is performed as follows:

$$W_i = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum\limits_{k=1}^{n} a_{kj}},\ i = 1,\ 2,\ \ldots,\ n \tag{7}$$

The AHP establishes clear user preferences for the future requirements of this product type, simplifies the complexity of design factors, optimizes the existing design methods, and provides new insights (as shown in Figure 2).

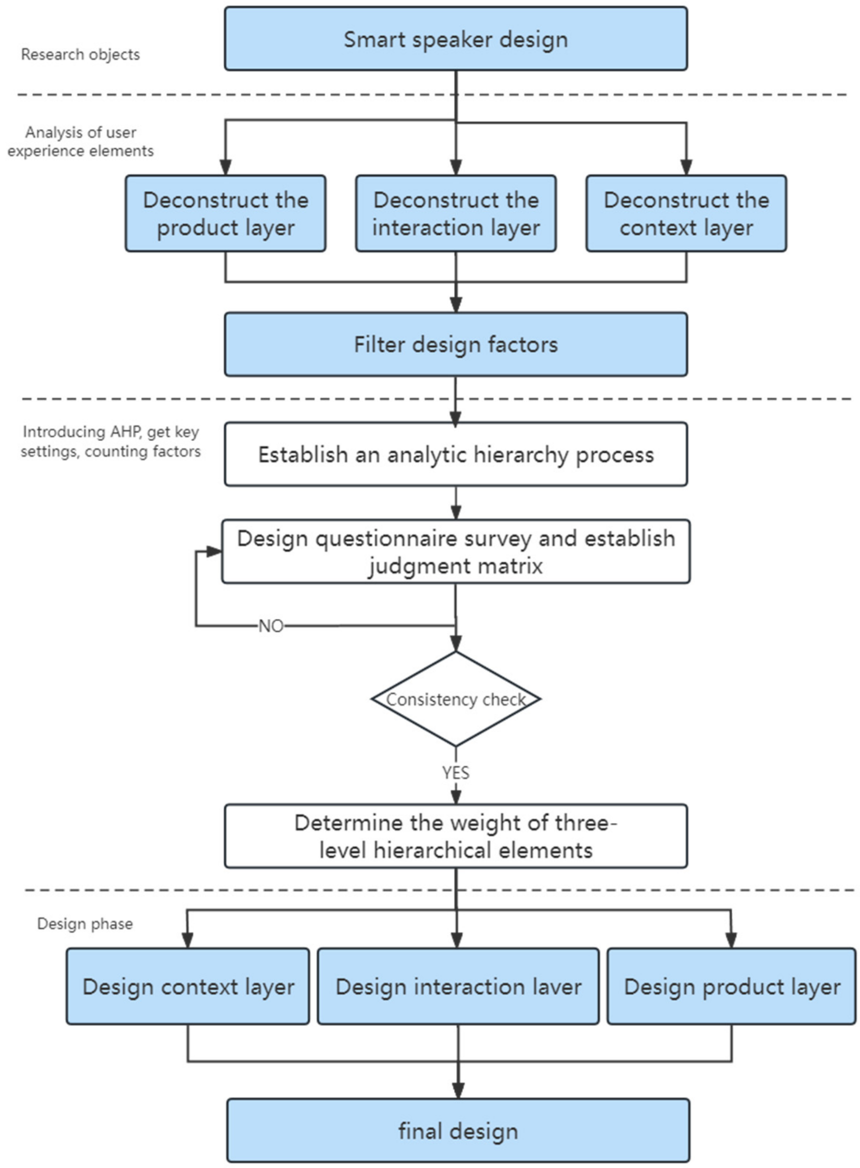

Figure 2. ViP design flowchart with the introduction of the AHP.

The operational steps of the analytic hierarchy process mainly comprise the following steps:

(1) Establish a hierarchical structure model: Divide the decision-making goals, factors to be considered (decision-making criteria), and decision-making objects into the highest level, the middle level, and the lowest level according to their interrelationships, and draw a hierarchical structure diagram. The highest level is the purpose of decision making and the problem to be solved; the lowest level is the alternatives when making decisions; and the middle level is the factors to be considered and the criteria for decision making.

(2) Construct all judgment matrices in each level: Use the paired comparison method and the scale of 1 to 9 to construct a pairwise comparison matrix of each factor in each level to the previous level. The paired comparison method is a pairwise comparison method in which two indicators are compared; the 1 to 9 scale refers to using a number between 1 and 9 to scale the relative importance of different indicators.

(3) Calculate the relative weight of the compared element to the criterion from the judgment matrix and conduct a consistency test: The necessity of conducting a consistency test on the matrix is that the judgment matrices we construct are all forward and reciprocal matrices. If the forward and reciprocal matrices satisfy a consistent matrix, the principle of consistency testing is to check whether there is much difference between the judgment matrix we constructed and the consistency matrix. The steps of consistency testing include calculating the consistency index, calculating the random consistency index, RI, calculating the consistency ratio, CR, etc.

(4) Weight vector and consistency index: The judgment matrix A obtained through pairwise comparison does not necessarily meet the reciprocity condition of the judgment matrix. The AHP uses a quantitative standard to measure the degree of inconsistency of the judgment matrix A. The formula of the consistency test is the average random consistency index * order RI.

In various applications, the analytic hierarchy process helps decision makers with program selection, resource allocation, prioritization, and risk assessment. For example, in business management, companies can use the analytic hierarchy process to determine the strategic goals of the company, as well as the measures and resource allocation required to achieve these goals. In project evaluation, the AHP can be used to prioritize projects for more effective allocation of resources and time. In addition, the AHP can also be applied to prediction and decision support systems. For example, in environmental engineering, the AHP can be used to evaluate environmental quality, predict environmental change trends, and formulate environmental protection strategies. In military command, the analytic hierarchy process can be used to evaluate the risks and benefits of military operations and provide support for military decision making. The application scope of the analytic hierarchy process is typically extensive. It can be applied to any decision-making scenario that requires the combination of qualitative and quantitative analysis and the comparison and weight analysis of multiple factors. This approach can assist decision makers in understanding and dealing with complex problems and improve the feasibility and effectiveness of decision making.

4. Smart Speaker Design Evaluation

4.1. Deconstruction Phase

This phase involves deconstructing the existing audio–visual products into product, interaction, and context layers, exploring the deeper emotions behind the products. Analysis of the product, interaction, and context layers of some existing products shows that the aim of the product layer is to identify the design features concealed beneath the external appearance or physical aspects of conventional smart speakers (as shown in Table 2). The interaction level considers the relationship characteristics reflected behind the interaction between people and products (as shown in Table 3). The situational level focuses on whether the interaction between people and products is determined by the contextual environment (Table 4).

The ViP (Value-in-Product) method was used to explore the design of a smart speaker, focusing on the product, interaction, and context layers. The analysis commenced at the product layer, focusing on the selection of the smart speaker. The design of the smart speaker incorporated materials, such as single plastic or composite materials, as well as a combination of various eco-friendly materials. This choice reflects the growing significance of sustainability in product design. Additionally, plastic and flexible silicone were used, contributing to the flexibility and durability of the overall design [17]. Various colors were used in the design of the smart speaker to convey different meanings. For example, red was used to imply warmth, whereas black and white represented fashion. Transparency was used to represent novelty. These color choices were intended to evoke specific emotions and create an aesthetically appealing product. The smart speaker was designed to be small and simple, occupying minimal space. This compact design facilitates easy placement in various environments without appearing obtrusive or bulky. The smart speaker offered various interactive behaviors in the interaction layer to enhance user experience. This included touch buttons, a screen interface, voice interaction, and lighting features. The functionality of the smart speaker was designed to be simple and user-friendly, ensuring that users could easily navigate through different functions and settings. However, it was observed that certain interaction modes occasionally caused user frustration, highlighting the necessity for further refinement and enhancement in this area. This insight underscores the importance of continuous improvement in user interaction design to ensure a seamless and satisfying user experience with smart speaker technology.

Table 2. Partial layers of the conventional smart audio–visual product.

Type	No Screen	With Screen	With Lighting
Legend	 ①	 ②	 ③
Color	Red body, red buttons	White body, black panel	Transparent body, black base
Material	Metal front mesh + eco-friendly ABS plastic + built-in fabric mesh	Plastic	Organic glass + plastic
Features	Voice assistant, music, and audiobook playback	Voice assistant, video display function	Voice assistant, water ripple breathing light effect
Dimensions (mm^3)	153 × 67.5 × 63	113 × 68 × 81.5	283.6 × 232 × 232

Table 3. Parts of existing intelligent audiovisual interaction layers.

Legend	Interaction	Interface	Features
1.	Buttons, voice, mobile app	Three buttons, large buttons, mosaic information, dynamic expressions, stylish and simple interface	Friendly, soft, passionate
2.	Touch, speech, machine-side interface, mobile-side interface	Three buttons, large button size, multi-touch, large black screen, increase visual feedback information	Calm, simple, stylish
3.	Buttons, voice, visual lighting	Combining indoor audio with integrated environmental lighting effects, experiencing music through ripple motion	Wonderful, warm, novel

Table 4. Some of the conventional smart audio–visual context layers.

Field	Development	Trend	Normality	Principle
Technique	Research and development of smart speakers; artificial intelligence; emphasis on user experience	Multi-sensory interaction; development of smart speakers; popular application of AR	Rapid iteration of smart products; audio–visual products are an indispensable part of home life	Establish the most harmonious relationship between products and users

Table 4. *Cont.*

Field	Development	Trend	Normality	Principle
Economy	Significant growth potential in the Chinese market; lower prices	Smart audio–visual products are becoming increasingly essential products in home life	Economic downturn; sustainable development	Safeguard people's livelihood; sustainable development
Social Policy	Favorable policies frequently introduced at the national level for the smart home industry	Increased human–computer interaction; towards social development	Support technologically innovative products	Raise the happiness index of the entire population
Psychology	Yearly decline in mental well-being	Desire for companionship; the desire for novel experiences; everyone needs to express themselves	Psychological stress; the love of beauty is a universal trait; preserve good memories	The aesthetics of life is an expression of lifestyle; situational
Culture	Homes aspiring to a better life	Adapting to the digital trend	Home decoration expresses feelings towards home and cultural cultivation	Discover and experience the beauty around you; change and improve your attitude towards life

The design of the smart speaker at the context layer was influenced by multiple domains, including technological, economic, social policy, psychological, and cultural factors [18]. These factors played a significant role in determining the characteristics and design considerations of the smart speaker. For instance, technological advancements influenced the integration of voice interaction, whereas economic factors determined the cost-effectiveness and affordability of the device. Social policies, psychological aspects, and cultural preferences also influenced the overall design to ensure it aligned with societal needs and expectations.

4.2. Quantitative Analysis of Design Metrics

During the design phase, designers have the freedom to develop products based on their sharp intuition according to the established ViP design principles. Designers use analogy methods to identify product characteristics from other reference context domains [19].

In the ViP design model combined with the AHP, an evaluation index system of the smart sound design was established to effectively guide the design process. Figure 3 illustrates this evaluation index system, which provides a comprehensive framework for evaluating the design of future products.

During the deconstruction stage, the designer gained an in-depth understanding of the design by integrating opportunity design. This allowed the designer to identify key factors that contribute to the success of the smart sound design. Subsequently, the AHP method was used to establish 12 evaluation indicators for the index layer, corresponding to the product, interaction, and situation criteria.

The rational quantification of these design factors is crucial in assisting designers to establish appropriate interactive relationships. By assigning weights to each factor, the AHP method aids in prioritizing and comparing the importance of different design elements. This quantification enables designers to make informed decisions based on objective criteria, leading to a well-balanced and effective design.

The 12 key factors identified in the evaluation index system include various aspects related to the product, interaction, and situation. For example, product factors may include sound quality, durability, aesthetics, and portability. Interaction factors might comprise user friendliness, ease of control, and responsiveness. Situation factors might encompass adaptability to different environments, cultural appropriateness, and social integration.

Designers can evaluate the design from multiple perspectives and ensure that all aspects are addressed adequately based on these factors. This holistic approach helps create a smart sound design that not only meets functional requirements but also aligns with user preferences, cultural context, and technological advancements.

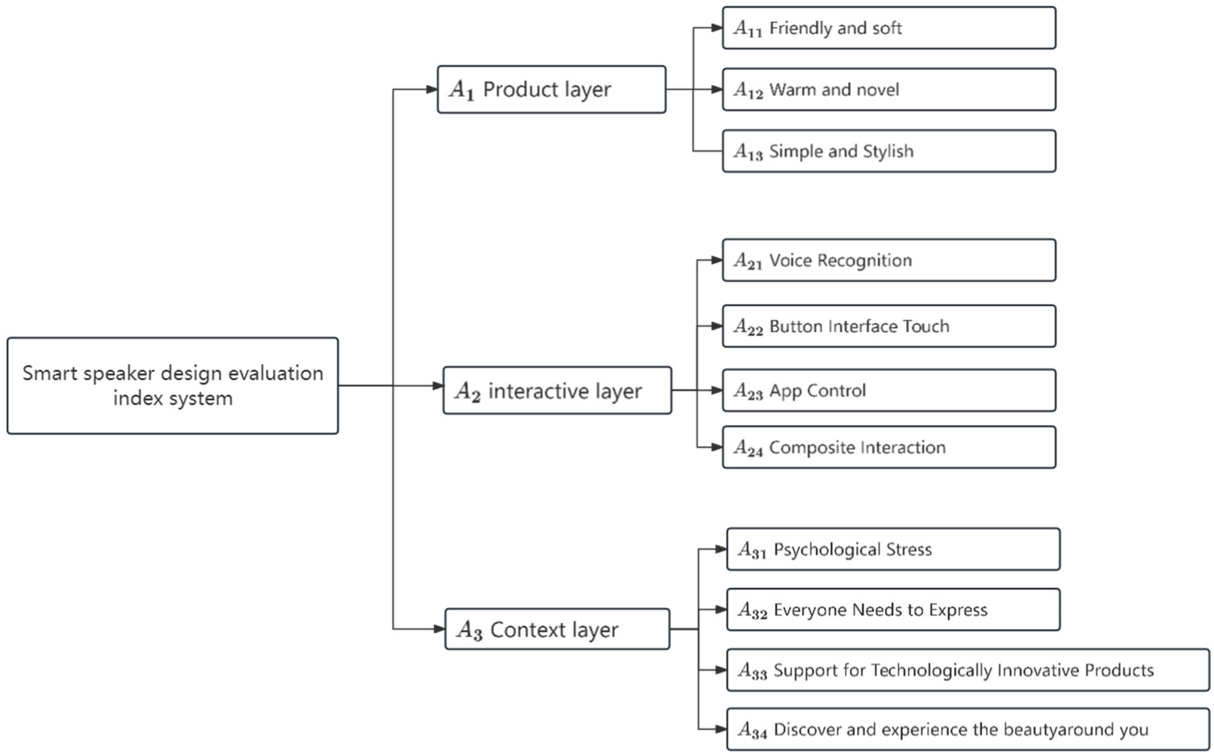

Figure 3. Design evaluation system of the smart home audio–visual product design.

A scale matrix was established using the questionnaire method, which involved surveying 67 users. A reliability test was conducted to ensure the reliability of the questionnaire, yielding a Cronbach coefficient α of 0.868. A Cronbach coefficient α above 0.8 indicates excellent reliability for the test or scale. A pairwise comparison of all factors was performed using a scale of 1–9, and the weight of each indicator was determined through the AHP method (as shown in Table 5).

Table 5. Weight values of each factor.

Criterion	Indicator Layer
A1 Product Layer	
A11 Friendly and Soft (4.18)	0.2583 0.2583 0.2605 0.2590
A12 Warm and Novel (4.36)	0.6370 0.6370 0.6333 0.6358
A13 Simple and Stylish (4.12)	0.1047 0.1047 0.1062 0.1052
A2 Interactive Layer	
A21 Voice Recognition (4.34)	0.0780 0.0779 0.0809 0.0789
A22 Button Interface Touch (4.39)	0.1891 0.1908 0.1948 0.1916
A23 App Control (4.37)	0.1188 0.1219 0.1244 0.1217
A24 Composite Interaction (4.54)	0.6140 0.6095 0.5999 0.6078
A3 Context Layer	
A31 Psychological Stress (4.22)	0.2050 0.2081 0.2122 0.2084
A32 Everyone Needs to Express (4.04)	0.0511 0.0509 0.0539 0.0520
A33 Support for Technologically Innovative Products (4.21)	0.1355 0.1392 0.1444 0.1397
A34 Discover and Experience the Beauty Around You (4.48)	0.6084 0.6019 0.5895 0.5999

In Table 5, a portion of the collected data and the obtained comparisons are presented, along with the derived AHP weights for each indicator within the criteria. This table provides transparency regarding the data collection process and demonstrates the objectivity of the obtained weights. The AHP weights were collected through a structured questionnaire survey involving participants experienced with smart audio systems. The questionnaire included criteria related to the product layer, interactive layer, and context layer, along with corresponding indicators. Participants provided pairwise comparisons of the indicators within each criterion based on their perceived importance. The responses were collected and aggregated to derive the weights for each indicator within each criterion.

The consistency of the AHP was assessed using the consistency ratio (CR) values. The CR values for the three methods used in the study were all less than 0.10, indicating that the consistency condition was met. This implies that the results obtained from the AHP analysis were reliable and accurate. To enhance the robustness of the results, weights were calculated using three different methods: the eigenvalue method, the geometric mean method, and the arithmetic mean method. The results showed that the indicator A12, representing Warm and Novel, had the highest weight ratio for the A1 Product Layer. For the A2 Interaction Layer, the indicator A24, representing Composite Interaction, had the highest weight ratio. Lastly, the indicator A34, representing Discover and Experience the Beauty Around You, had the highest weight ratio for the A3 Context Layer. These results indicate the significance users attribute to warm and novel product designs, composite interaction modes, and the ability to discover and experience beauty in their context. Designers can consider these factors when creating new smart audio devices and interactions. By prioritizing these factors, designers can create products that are not only functional but also aesthetically pleasing and enjoyable to use. In summary, the AHP method provides a valuable tool for designers to identify and prioritize user satisfaction factors across different layers of the product design process. Using this approach, designers can create products that meet user expectations and deliver an outstanding user experience. The results of this study also provide insights into the design of smart audio devices, guiding future research and development in this rapidly evolving field.

5. Design Examples

The design evaluation system for the smart home audio–visual products integrated weight values of various factors [20]. Design factors such as warm and novel, composite interaction, and discovery and experience of the beauty around were used at the design stage of the ViP design model. Warmness and novelty were used as the product characteristics, exhibited through physical attributes and interaction methods to demonstrate the refinement of the design.

5.1. Context Layer Design

In today's fast-paced era society, people often find themselves caught up in the hustle and bustle of daily life. As a result, they may not have the opportunity to slow down and appreciate the beauty that surrounds them. This lack of time for critical exploration can lead to a sense of disconnect from their surroundings. To address this issue, the aim of the final design was to create a smart speaker that allows people to explore the beauty of music visually. By incorporating visual elements into the audio experience, users can not only listen to music but also visually perceive its expression and impact [21]. This integration of audio and visual stimuli aims to amplify the beautiful details in life and provide a multi-sensory experience. The smart speaker can be equipped with a display screen or LED lights that synchronize with the music being played. Integrating a visual component can enhance the overall experience by creating a captivating and immersive atmosphere. For example, the display screen can feature mesmerizing visuals that correspond to the rhythm and melody of the music, or the LED lights could dynamically change color and intensity based on the emotional tone of the songs.

By combining audio and visual elements, the smart speaker encourages users to pause and appreciate the beauty and intricacies of the music they are listening to. It provides an opportunity for them to reconnect with their surroundings and discover new dimensions of enjoyment in their daily lives.

The final design of the smart speaker aims to enable people to explore the beauty of music visually. By incorporating visual elements into the audio experience, users can have a more immersive and enriching sensory experience. This design concept seeks to encourage individuals to slow down, appreciate the beauty around them, and find joy in the small details of life.

5.2. Interactive Layer Design

The attributes of warmth and novelty in the product are described in terms of the use and operation of the product [22]. New products should have warm and novel interactive experiences and foster interactive relationships. Comprehensive interaction provides powerful support for the users' warm and novel experience. The interactive relationship should transition from product dependence on users to mutual dependence and warmth [23]. The interactive trait can be described metaphorically as "a ray of light outside the window, illuminating our lives" (Tables 6 and 7).

Table 6. The previous interaction relationship.

User Status \ Product Interaction	Needs Awakening	Active Interaction	Interactive Balance
Independent	1	2	3
Mutual dependence	4	5	6
Dependence	7	8	9

Table 7. The current interaction relationship.

User Status \ Product Interaction	Need to Wake Up	Active Interaction	Interactive Balance
Independent	1	2	3
Mutual dependence	4	5	6
Dependence	7	8	9

Previous interaction state: The user state is dependent (people play music through the machine), and product interaction needs to be awakened (for example, voice control).

The subsequent interaction state: the user state is interdependent (people play music through the machine, and the machine needs people to explore the beautiful things around them and push interesting songs).

Product interaction is an interactive balance (no longer only controlled by voice, people play music by taking photos, which adds more sense of participation and triggers emotional resonance).

A new song playback interaction method was added to the design. In addition to the existing voice control, physical buttons, machine-side touch interface, and app control, users can now add songs through photos and print them in real time, introducing a completely new interactive experience, enhancing product usability, and achieving a balanced interaction. This new feature enables users to search for music using their eyes, express themselves through music, and preserve the music through photos. The machine side and the mobile app side use Bluetooth technology to connect to the home Internet of Things, allowing users to set up the smart speaker using buttons, touch interfaces, and mobile phone applications (as shown in Figures 4–6). Physical buttons on the device offer various functions, such as taking photos, printing, switching the machine on/off, and adjusting volume. The touch interface on the machine side allows users to view lyrics, preview images, and enhance printing. The mobile app is synchronized with Bluetooth data and is structured into four main sections: the home page, playback page, shop, and my four boards [24]. The home page is the music photo album. By combining the act of taking photos with music, every delightful song represents the little moments of a beautiful life, filled with a sense of cherish and nostalgia [25]. This aligns with the envisioned interactive characteristics, which are akin to “a ray of light outside the window, illuminating our lives” .

Figure 4. Button interaction of the smart camera and audio device.

Figure 5. Machine-side interaction interface of the smart camera and audio device.

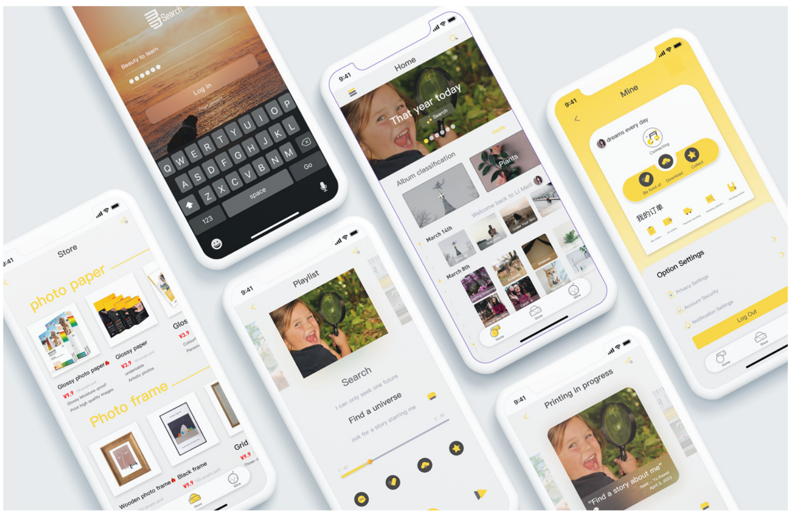

Figure 6. Interaction interface of the smart camera and audio app.

5.3. Product Layer Design

The warm and novel product characteristics represent the inherent features of the product. The product design is inspired by the magnifying glass in our daily lives, as depicted in the physical model (as shown in Figure 7). The appearance of the product mimics the distinctive features of the magnifying glass, which is interesting, and the details of the large, round corners imbue a sense of warmth and appeal to users. ABS plastic is used as the primary material, which is safe and non-toxic. A color scheme featuring a combination of deep yellow and subtle gray is adopted. The deep yellow stands out amidst the neutral color, highlighting the illumination of light in the ordinary aspects of life, providing a touch of warmth, even in small amounts [26]. The design draws inspiration from recent trends in home decor, allowing the product to naturally integrate into home settings.

(a) (b)

Figure 7. Physical model: (**a**) front view of the physical model; (**b**) back view of the physical model.

When users see the camera, screen, speaker port, and printing area, their first impression may not entirely grasp the nature of the product. However, every function aligns with the user's mental model of its usage, prompting users to contemplate the possible behaviors and operations the product might trigger. The novel characteristics attract users to interact with the product and subtly indicate how to operate it [27]. These mysterious and novel product characteristics demonstrate a human-centered design approach, providing users with warmth. It addresses the usability limitations, lack of humanization, lack of interest, and emotional care observed in conventional products of a similar nature. The design meets the actual needs of users for this product in the foreseeable future [28–30].

6. Conclusions

In conclusion, our study proposes an innovative design approach that combines the ViP design principles with the AHP to effectively enhance the interaction status of smart audio devices and elevate user experience. By integrating these methodologies, we introduce novel interaction modes that address the limitations of previous research and existing smart speakers, which predominantly rely on voice interactions.

The application of the ViP principle within the product–interaction–context layers, exemplified by our physical smart speaker model, allowed for a comprehensive consideration of user interactions, leading to the identification of new design opportunities. Furthermore, the AHP facilitated the quantification of design factors, enabling designers to define product characteristics and guide the development of the product's model and interactive behaviors.

While our study analyzed and quantified a limited number of user samples, we recognize the importance of expanding our research scope. In future studies, we plan to increase the number of user samples and explore multiple product schemes to further validate our findings. Additionally, the integration of virtual contexts will be pursued to validate user satisfaction with future products.

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