Research article

Research on interactive product design of museum information based on embodied cognition

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ABSTRACT

Objective To explore the design method of museum information interactive products under embodied cognition, so as to improve the problem of users' decreased interest in traditional culture caused by their inability to feel the charm of cultural relics when visiting museums. Methods A new concept "information interactivity" was proposed based on information visualization from the perspective of embodied cognition, and the existing pain points of museum communication mode and user journey map were analyzed on this basis. At the same time, the factor relationship of information interactivity products under embodied cognition was constructed, and the relationship between "environment, body and brain" under multi-sensory interaction environment was analyzed. And the difference between user cognition and experience. Results The design practice was carried out by taking the stork fish stone ax painted pottery jar in Yangshao culture as a case. Through constructing environment and guiding user behavior, users were stimulated to have a deep cognition of information objects in the process of interaction with information, and the feasibility of information interaction under embodied cognition was explored. Conclusion Based on the embodied cognition theory, a product design method for museum

information interactivity is proposed. Through reproducing cultural environment, immersive multi-sensory interaction and weaving cultural cognition, users can improve their sense of cultural identity and experience, which provides a new method for the development of museums.

Keywords: Embodied cognition; Information can be interactive; AIGC; A museum

0 Background

Technological advancements have diversified the means by which humans access information, with the maturation of VR, AR, and MR technologies notably driving the evolution of human-information interaction.Designers are exploring the integration of digital information, humans, and space to enhance user experiences in information acquisition. Historically, digital information was presented in two dimensions through visual languages such as images and text on digital media. Presently, technology enables the transition of digital information to a three-dimensional space, fostering an environment for direct user-information interaction, thus enhancing acquisition efficiency.Designers, responding to the growing demand for sensory experiences in information acquisition, extend beyond visual optimization. They engage multiple senses to create immersive, relaxed, and enjoyable experiences, thereby improving information acquisition efficiency.Museums, as key channels for cultural heritage, can benefit from digital empowerment to accelerate their development and cultural spread, aiding users in accessing artifact information and perceiving

cultural essence. However, user information acquisition efficiency in museums is subject to personal and external influences.This paper introduces the concept of "interactive information," grounded in embodied cognition theory, and integrates it into museum design and application. The "Geese and Stone Axe Painting Pottery Jar" interactive product serves as a case study, offering innovative methods for cultural perception and exploring new avenues for museum development in the modern era.

1 Embodied cognition and information interactivity

1.1. Research status

Museums are the epitome of human culture and national spirit. By collecting and exhibiting material and intangible heritage of various historical periods, museums promote the formation of human outlook on life and values, and play a huge role in promoting social development. In order to promote the creativity and vitality of cultural communication, more and more museums are constantly trying to innovate communication methods, such as setting up online digital exhibition halls, so that users can obtain cultural relics information through computers, mobile phones and other media, and setting up many interactive elements in the digital exhibition halls to enhance users' sense of participation. However, at present, the cultural relics exhibited online in most museums

are only flat pictures, and the expression of cultural relics information is lengthy, so users cannot quickly and effectively obtain information, and interaction with users is limited to simple operations such as sliding and translation, which cannot effectively arouse users' interest, resulting in users' understanding of cultural relics remaining in the text stage [1]. Offline, although many museums use VR, holographic projection and other technologies to provide users with immersive visiting experience, the design is still centered on the collection, and the location of interactive devices is fixed, and the corresponding interactive exhibits are few, which cannot meet the needs and experience of each visitor [2].

With the development of embodied cognition theory, people gradually realize the important role of the body in the cognitive process. Embodied cognition believes that the cognitive process of human beings is not only the activity of the brain, but also the interaction of the body and the influence of the environment [3]. This theory provides a new idea for the design of interactive museum information products. Through the combination of physical interaction and digital technology, users' visiting experience can be effectively enhanced, and users can have a deeper understanding of cultural relic information in the interaction process [4].

At present, researchers at home and abroad have begun to try to apply embodied cognition theory in museum exhibitions. For example, through motion capture technology and motion-sensing interactive equipment, users can interact with the exhibits through body movements, thus deepening the understanding of the exhibits [5] [6]. Some museums have also introduced augmented reality (AR) and mixed reality (MR) technologies, which superimpose virtual information on real exhibits that users can interact with through mobile devices or special glasses [7] [8].

In spite of this, the existing embodied cognitive interaction product design still has some shortcomings. For example, interactive design mostly focuses on the display of a single exhibit, lacking systematism and integrity [9]. In addition, some interaction designs are too complicated, which increases the difficulty of users' operation and affects users' experience [10]. Therefore, how to better apply embodied cognition theory in the design of museum information interactive products to make interactive design more humanized and convenient is still an urgent problem to be solved.

1.2. Overview of embodied cognition

Mbodied cognition, alternatively termed "enactive cognition," emerged in the 1980s, highlighting the pivotal influence of bodily experiences and

actions on cognitive processes [11]. Characterized by enaction, embodiment, and environmental embeddedness [12], it posits that users, when acquiring information, are inherently situated within an environment. The body's response to environmental stimuli is communicated to the brain, which in turn generates corresponding cognitive responses, prompting the body to act in accordance with the environment (as depicted in Figure 1). Embodied cognition is contingent upon experiential formation through the perceptual, behavioral control, and meaning construction layers, fostering a connection between the body and its surroundings[13].Scholars domestically have garnered notable achievements in the realms of cultural innovation, human-computer interaction, and product design, grounded in embodied cognition theory. With the swift evolution of emerging digital technologies, the brain, body, and environment are regarded as distinct yet interconnected entities. This multi-tiered analysis of user experience paves the way for theoretical underpinnings that enhance user experience and inform product design within the realm of interaction design. Practical applications include the creation of virtual museums through technological innovation, exemplified by digital exhibition halls in Chinese museums, the Science and Technology Museum in Milan, Italy, and the "Google Arts & Culture" project. These initiatives situate the user's body within an environment, overcoming the constraints of space and time to deliver an

immersive experience. The interplay between humans and their environment, as illustrated by embodied cognition, offers the foundational rationale for the design of information hierarchies and interactive gestures in interactive experiences [14]. Consequently, this paper adopts embodied cognition as its theoretical framework, offering both theoretical grounding and practical directives for the study of interactive design in museums.
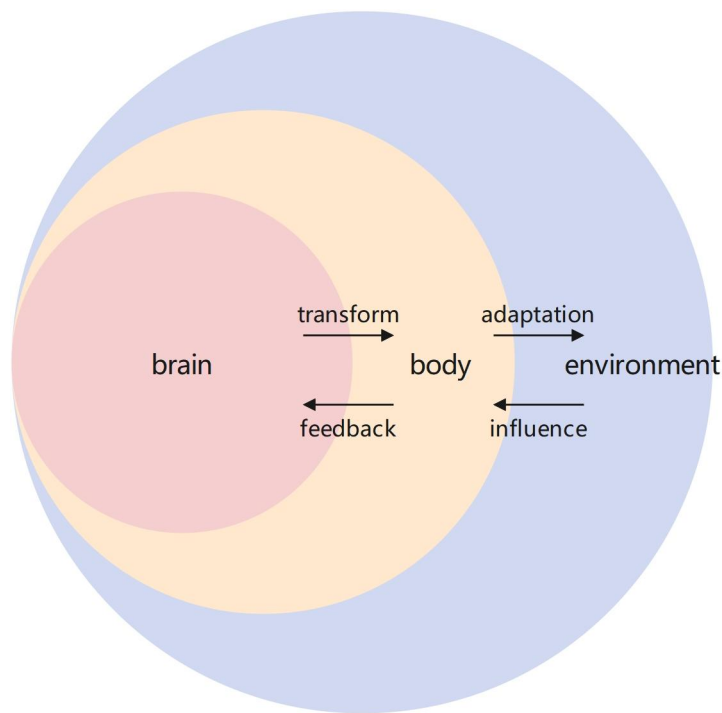

Figure 1 Relationship of embodied cognitive structure

1.3. Interactive overview of information

Information visualization swiftly captures the user's visual attention, effectively stimulating comprehension and cognition, facilitating the efficient acquisition of information [15]. In the realm of digital

information, an increasing array of visualization products now incorporate interactive functionalities, transitioning the user's interaction with information from a unisensory to a multisensory experience. This transition is achieved by elevating the user's physical engagement, which in turn, enhances the efficiency of information acquisition. With the advent of AIGC technology, data presentation has become more intelligent, personalized, and efficient, capable of generating tailored information content autonomously in response to user requirements.

Prior research and practice in the expression of information content design have predominantly concentrated on the visual transformation of information, overlooking the capacity of other bodily senses to receive information. This oversight does not fully satisfy the current demands for information design and dissemination. To augment both the efficiency and experiential aspects of information acquisition, the concept of "interactive information" is proposed, predicated on information visualization.Interactive information denotes a dynamic process where users can interact with information within the same spatial context through physical gestures and sensory engagement, eliciting corresponding feedback. This approach surpasses traditional information visualization by emphasizing the activation of multisensory experiences within an immersive environment. It not only bolsters the user's control

over information but also fosters value co-creation through the interplay between the user's actions and the information itself. For example, Apple Inc.'s Vision Pro utilizes motion capture and eye-tracking technologies to facilitate user operations within a mixed reality environment, presenting product information in a three-dimensional format that enhances user comprehension and experience. Meta's Quest3 even enables users to construct models within a virtual space.In the context of museum design applications, interactive engagement with artifact information immerses users in a historical and cultural continuum, potentially elevating their cognition and appreciation of cultural relics. This approach not only enriches the user experience but also advances the promotion and dissemination of culture. Consequently, this paper integrates the concept of interactive information into museum design applications, endeavoring to offer efficacious strategies for museum evolution.

2 Design and analysis of information-interactive products based on embodied cognition

2.1 Feasibility analysis of product design

The establishment of a user experience journey map during museum visits, coupled with the analysis of the emotional experience curve, facilitates the identification of pain points and opportunities within the museum visitation process (as depicted in Figure 2). Predominantly, the

pain point lies in the fact that users' cognition of exhibits in museums has traditionally been confined to the understanding of textual and graphic information and the interpretations provided by guides, resulting in a passive state devoid of active, in-depth exploratory experiences. This limitation hinders users, despite their physical presence in the museum space, from effectively establishing a connection with the cultural relics. Embodied cognition theory underscores the importance of real-time interaction [16]. For users, the traditional methods of cultural communication in museums lack a sense of engagement and experience, preventing a profound cognitive understanding of the cultural relics. It is only through active physical and mental engagement with the cultural relics in the museum, through perception and interaction, that users can deeply comprehend the significance of the relics and forge a connection between the body and the environment [17].

With technological advancements, users now seek more profound interactions with information, desiring it to be presented in an interactive format that transcends the constraints of audio-visual transmission and reception. In environments such as virtual reality and mixed reality, users can control their behaviors to interact with cultural relics, engage in creation or re-creation in non-physical settings, and receive immediate feedback on information outcomes. Interactive experiences with cultural

relics allow users to effectively perceive the informational value embedded in the environment, utilizing media or tools to bridge the spatial gap between users and information. This process results in a profound and multifaceted understanding of cultural relic information, with different user behaviors potentially leading to varied cognitive interpretations of the same exhibit, challenging the traditional cognitive psychology's axiom that "cognition is computable" [18]. Thus, the innovative integration of embodied cognition with interactive information can construct a multidimensional cultural perceptual experience.

Museum information products designed under the guidance of embodied cognition theory shift the design focus from objects to people, employing digital technology to humanize cultural relics. By fostering interactive elements within the environment that stimulate bodily functions, and promoting multisensory interaction between the body and cultural relics, the user's physical experience and cognitive capacity during the perception process are enhanced. Such environmental interaction can yield an immersive cultural experience, evoking emotional responses from users, with positive emotional experiences forming the foundation for sustained user engagement [19-20]. Museums, with their inherent historical attributes and cultural connotations, often inspire a sense of reverence in users when viewing exhibits. Information interactive

products guided by embodied cognition theory can integrate technology with the environment to recreate historical scenes, directing the user's physical behaviors and activities, and facilitating an immersive understanding of traditional cultural connotations. Ultimately, this approach fully leverages the museum's role in cultural dissemination and education. By creating an interactive environment, the distance between users and cultural relics is shortened, allowing museums to transition from active narrative agents to passive ones, thereby reinforcing the user's bodily cognition. In conclusion, this paper employs embodied cognition as its theoretical foundation and interactive information as its design approach, which can, to a certain extent, yield products that align with the future development of museums.
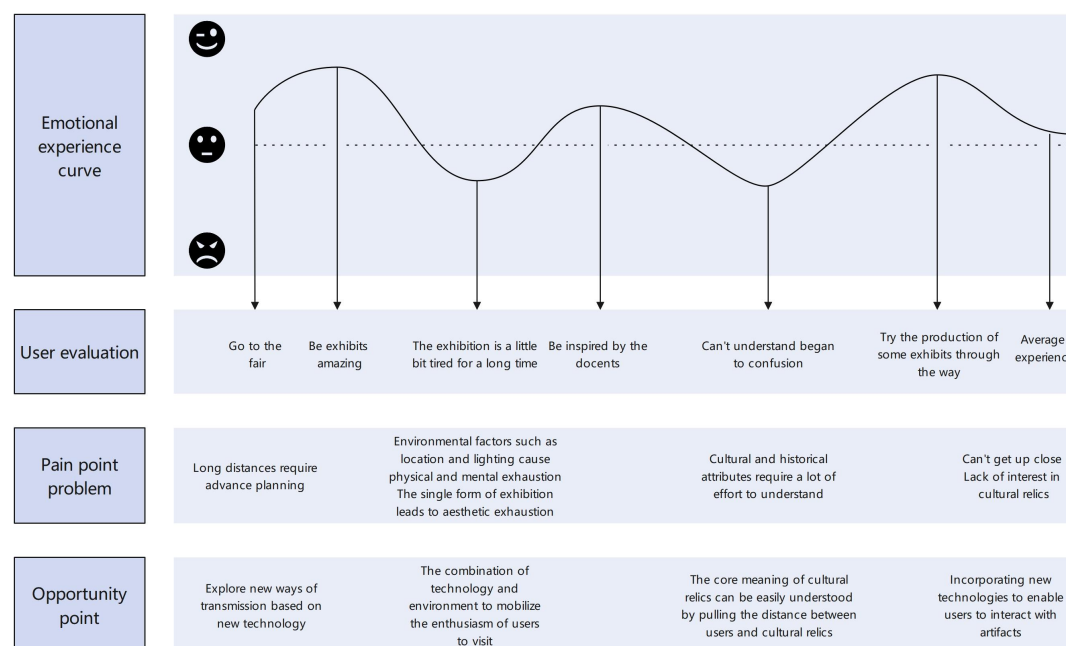

Figure 2 User journey diagram

2.2 Construction of factors of information interactive products under embodied cognition

To augment the efficacy of cultural communication within museums, enhance the experiential quality of museum visits, and amplify cultural perceptiveness, this article delineates a relational framework for interactive museum information products predicated on embodied cognition, as depicted in Figure 3. A novel scenario relationship is established, comprising the perceptual layer (environment), the behavioral control layer (body), and the meaning construction layer (brain), to address the aforementioned issues. The design is segmented into three distinct components: contextual design, behavioral design, and cognitive formation. This approach engenders an immersive experience for users within the scenario, allowing them to perceive cultural connotations, establish a corporeal-environmental relationship, and generate new experiential feedback to the brain. The brain, informed by emergent cognition and accrued experience, subsequently catalyzes novel behavioral responses from the body within the environment, thereby instituting a cyclic and iterative process of information interaction.

2.2.1 Body perception layer

The perceptual layer, which denotes the relationship between the body and the environment, forms the basis for physical activities and the

cognitive processes within the brain. Utilizing wearable mobile devices, users can perceive aspects of their surroundings such as color, form, texture, lighting, temperature, and thematic elements. While navigating the physical confines of a museum, visitors are immersed in cultural relics and interactive elements brought to life through technologies like digital modeling and holographic projection. Each cultural relic is distinctively rendered, reflecting its unique historical context. For instance, the "Along the River During the Qingming Festival" painting, which portrays the prosperity and happiness of the Northern Song Dynasty's capital, is associated with joyful colors, prompting the environmental space to adopt festive hues like red and yellow. This color scheme facilitates a rapid integration of users into the cultural narrative.

Surrounding the relics, elements intimately connected to their stories emerge, providing a more authentic reenactment that diminishes the spatial gap between users and the relics and accelerates the users' spiritual engagement with the culture. AIGC technology is concurrently harnessed to deliver personalized service experiences tailored to individual preferences. This includes the visual representation of digital restoration and enhancement of cultural relics, personalized virtual tour guide interpretations and companionship, and adjustments to environmental factors based on personal perspectives.Cultural relics are presented digitally to users, and interactive technologies are employed to allow for

interaction without causing harm, enabling the acquisition of cognition and experience throughout the information interaction process. In an environment that seamlessly blends the virtual and the real, embodied interaction and profound experiences lead to a tight coupling between the user's body and the environment, fostering a deeper cognitive understanding [21]. Previously, museum visitors relied solely on their auditory and visual senses to engage with cultural relics. However, in a mixed reality setting, the reenactment of scenes, the transcendence of time and space, and the interactive experiences prompt a "dialogue" between users and relics, allowing for a more comprehensive appreciation of cultural charm.After engaging with the interactive information of cultural relics, each user attains a unique cognitive experience. The dynamic interplay of information and user behavior further enriches the environment, integrating both users and cultural relics as integral components of the setting.

2.2.2 Behavior control layer

The behavioral control layer encompasses the bodily response to environmental stimuli, wherein sensory organs elicit perceptions that inform corresponding actions. The body, as the principal of action, is subject to pre-experience schematic influences that foster an abstract understanding of the environment, as well as to the concrete and dynamic

experiences shaped by embodied interactions, often leading to divergent perspectives. Before the experience, users predominantly utilize auditory and visual senses to assimilate information, drawing upon past experiences to form a rudimentary grasp of the superficial aspects of cultural relics, constrained by temporal and spatial limitations and reliant on subjective associations for interpretation and judgment.

Throughout the experience, the cultural relics' context is technologically recreated to establish a user-centric interactive environment. Diverse experiential events are crafted to encourage users to integrate their preconceived cognition into the interactive experience with the relics. Through exploration and interaction with the environment and relics, users attain a richer, multi-layered sensory and experiential understanding, culminating in a sense of comfort and pleasure [22]. The design of the relics' functional structure, interaction modalities, and bodily actions capitalizes on the intrinsic spiritual and emotional qualities of the relics to devise a spectrum of visual, auditory, tactile, and olfactory interactions. This strategy guides users to a profound comprehension of the relics' information during the interactive process, ultimately inciting an emotional resonance and an immersive experience.

Information transcends the confines of audio-visual dissemination, becoming perceptible and interactive within a multi-dimensional spatial context. The interactions between users and cultural relics evolve into

more natural engagements, endowing the body with a heightened sense of authenticity, thus aiding in the construction of environmental understanding [23]. Furthermore, the information exchange between users and the environment during the immersive experience necessitates real-time and dynamic qualities to avert perceptual discord and a sense of disconnection. Interactive elements provide cues and guidance that facilitate the establishment of bodily mappings within the object, fostering more tangible practical cognition and visceral sensations. This enhances the bond between the body and the environment, reducing the cognitive effort required to grasp the core tenets of culture and elevating the gratification derived from the experience.

2.2.3 Meaning building layer

The meaning construction layer pertains to the significant and proactive cognitive reflections and experiential engagements that users develop in relation to their environment following interactive processes. Merleau-Ponty asserts that experience is a precursor to reflection, with perception and consciousness being mediated by the body to establish a presence "in the world" [24]. The museum experience can be bifurcated into two principal categories: reflection stemming from the juxtaposition of past and present experiences, and reflection emerging from the contrast between the sensation of virtual space existence and the immersive

experience characterized by "human-computer unity" and a state of self-effacement. From an interactive standpoint, the former is engendered by the diminishment of spatial distance, which narrows the gap between "person and environment," thereby enabling a more profound perception of cultural relics. For instance, in comparison to traditional cinema, the viewing of 3D films allows users to more vividly experience the sensory stimulation conveyed by the plot, leading to a more enduring impression of the narrative context. The latter is facilitated by digital technology that extends the corporeal experiences and cognition of individuals from the physical realm into the digital sphere [25]. Environments designed with attributes such as entertainment value, immediate feedback, and ease of understanding guide users to autonomously engage in interactive processes that interest them. This design enables users to immerse themselves in the historical and narrative context inherent in cultural relics, evoking emotional responses that foster an empathetic effect. Consequently, this leads to a convergence of the physical body's sensations in the tangible world with the emotional experiences of the intangible, achieving a harmonious unity of body and mind. For example, a diver utilizing fins to swim underwater extends their bodily perception to the fins, propelling themselves with greater speed and less effort, with the fins effectively integrating into their cognitive perception of their body. Reflecting on past experiences significantly amplifies the capacity

for meaning construction [26]. This reflection evolves from contemplating innate perceptions to considering bodily behavioral experiences and ultimately to contemplating the environment, forming a cyclical and iterative process that deepens the cognition of the object of perception. By presenting information in an interactive format, the "environment-body-brain" continuum is established as an integrated whole, allowing users to develop a comprehensive understanding of cultural relics during the interactive process. This approach satisfies the users' cultural aspirations and fulfills the museum's objectives of dissemination and education.
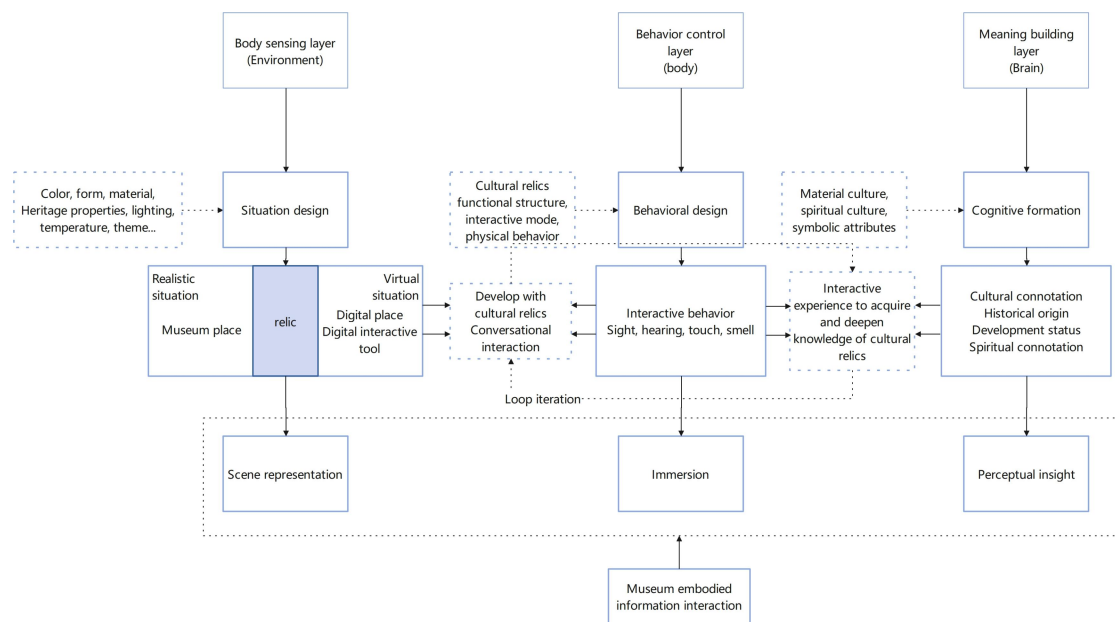

Figure 3 Construction diagram of factors of interactive products of museum information under embodied cognition

3 Design practice of information-interactive products based on embodied cognition

3.1 Spatial content design and transformation

The design of the product is approached through the three dimensions of the subject object, environment, and interactive elements, addressing perception, behavior, and cognition, as shown in Figure 4. To enable a more intuitive interaction with exhibits, the interactive process is crafted such that users engage with cultural relics using fundamental gestural actions. The experiential sequence is initiated once users equip the device; the Geese and Stone Axe Painting Pottery Jar materializes digitally within their visual scope, while the tangible version of the artifact progressively fades into the background. The environment surrounding the user populates with elements associated with the jar, such as depictions of tribal battles that honor the valorous acts of a chieftain, as portrayed on the vessel. Interactive elements encircle the digital representation of the jar, inviting users to make selections that guide them through various interactive pathways.This study employs the pottery-making process as a paradigm, directing users to actively participate in the creation of the Geese and Stone Axe Painting Pottery Jar. This encompasses the artistry of pattern drawing, color selection, material choice, form molding, and temperature regulation, culminating in the production of an

individualized "Geese and Stone Axe Painting Pottery Jar." By ceding control of the interaction to the user, the experience is rendered from an embodied vantage point, amplifying the user's cognitive engagement with the exhibit. The integration of an entertaining process and the potential for diverse outcomes stimulates a deeper investigation of the Geese and Stone Axe Painting Pottery Jar, nurturing a user's inclination toward sustained cognitive and experiential acquisition within an immersive spatial context.
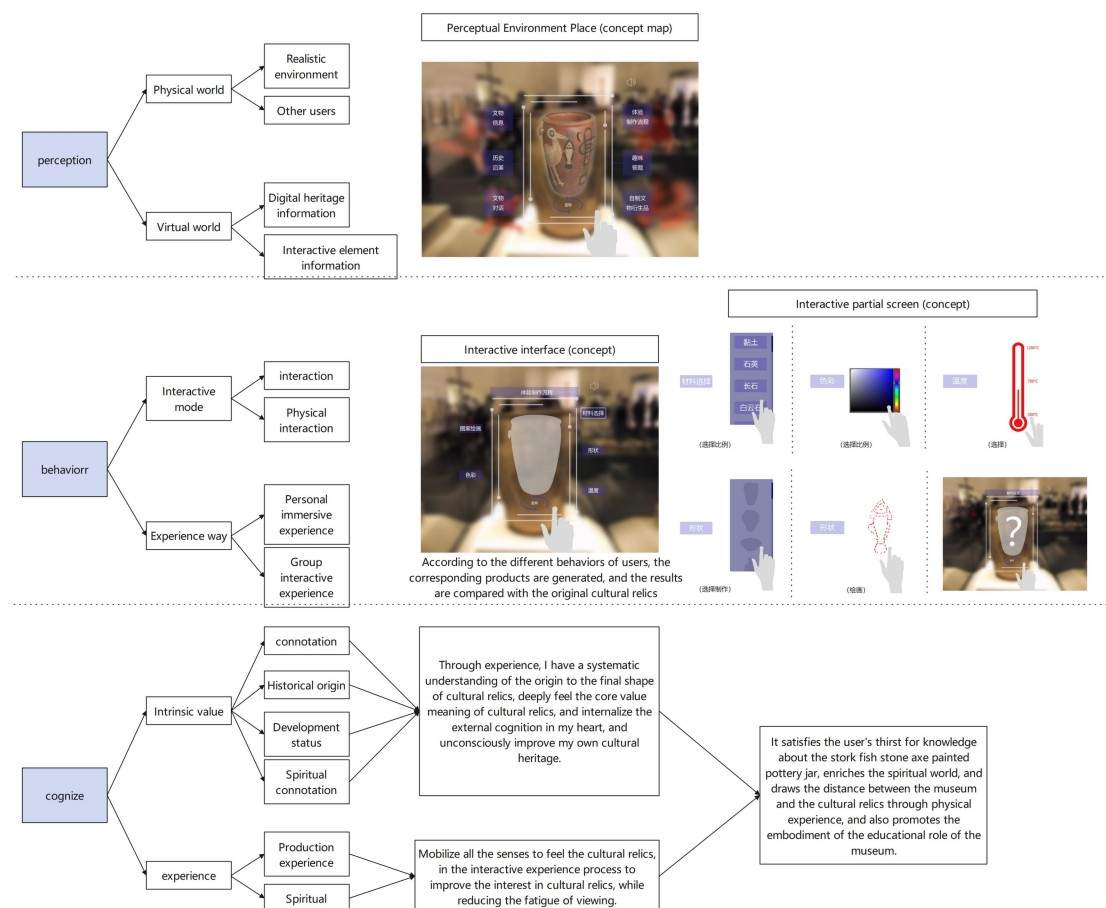

Figure 4 Interactive product concept diagram

3.2 Experience the spatial setting

Users traverse the museum's mixed reality environment clad in interactive equipment. Information technology augments the details of the ambient setting, fabricates lifelike virtual elements, and generates environmental sounds, thereby synergistically engaging the users' visual, tactile, and auditory senses to intensify the immersive experience. Voice and gesture recognition technologies are leveraged to amplify user control during interactions, invigorating their proactivity. Propelled by their inquisitive nature, users exhibit an increased propensity for environmental exploration and engagement.

In the interactive process, the scene setting is initially established by elucidating the significance of the Geese and Stone Axe Painting Pottery Jar, capturing the visual attention of users and piquing their interest in the artifact. Subsequently, ambient audio cues are employed to activate the auditory senses, instilling a sense of presence. The interactive features of information are then harnessed to direct the user's experience, with bodily movements and experiential feedback during the interaction providing cognitive insights, culminating in a comprehensive understanding of the intricate and profound information pertaining to the Geese and Stone Axe Painting Pottery Jar.Divergent from conventional interactive paradigms, as users enter the designated area, thematic elements associated with the

Geese and Stone Axe Painting Pottery Jar emerge incrementally, encircling the user. Upon nearing the exhibit, interactive components manifest around it, facilitating real-time interaction with the cultural artifact. Post-interaction, AI facilitates a comparative analysis between the original Geese and Stone Axe Painting Pottery Jar and the user's creation, identifying disparities and offering constructive feedback. This process enhances user retention and incites a desire for challenge and knowledge acquisition.Throughout the interactive journey, users progressively assimilate the role of creators of the Geese and Stone Axe Painting Pottery Jar. Through an ongoing cycle of learning, manipulation, and refinement of information interaction, emotional attachment to the artifact is fostered, culminating in a profound spiritual resonance.

In a broader context, the use of wearable devices grants users the liberty to navigate an environment where information is interactively accessible. This autonomy enriches the museum visit, enabling deeper immersion in the museum's cultural tapestry. The necessity to deliberately engage with specific interactive products to glean information is obviated, thereby diminishing the perceived chasm between users and the museum. This subtle yet significant shift is instrumental in actualizing the museum's educational mission.

3.3 Weaving and setting of cognitive dimension

Users typically engage in interactive experiences with defined objectives, necessitating that products continually evoke a profound comprehension of cultural artifacts to satisfy user requirements. From a user-centric viewpoint, the interactivity frequency of elements, the immersive quality of the environment, and the precision of content significantly shape the understanding of cultural artifact information. Conversely, from the museum's perspective, the efficacy of interactive methods in facilitating communication, the ability of users to decode deeper informational connotations, and the targeting of user demographics are considerations that merit in-depth examination. Consequently, the design employs interactive explicit knowledge to guide users autonomously toward an understanding of implicit information.

In the contextual dimension, the information associated with the Geese and Stone Axe Painting Pottery Jar is recreated, enhanced with auditory effects, seamlessly integrating users into the socio-historical milieu of the artifact's creation. On an individual level, the body's actions within the interactive process yield corresponding outcomes, affording users a more vivid cognitive experience. Temporally, from the onset to the culmination of the interaction, the body amasses new experiences, progressively deepening the understanding of the Geese and Stone Axe Painting Pottery

Jar. By integrating the triad of "environment, body, and brain," an intricate cognition of the artifact's intrinsic information is ultimately achieved.

4 Conclusion

This paper, which underpins its investigation on the design of interactive museum information products with embodied cognition, theoretically amends the shortcomings in physical perception inherent in traditional museum interactive installations. It also introduces the innovative concept of interactive information to the conventional museum visitation model, transcending visual information reception to engage users in a multisensory dialogue with cultural relics. By animating these relics through technology, the approach serves both as a conservation of cultural heritage and as a means to provide users with a deep cognitive experience. Furthermore, it enhances the cognitive and educational experience of museum visitors, fostering the digital dissemination and evolution of museums.

Despite certain limitations due to technological constraints that impede more profound research, the transition from visual to interactive information is poised to pioneer novel methods of cultural communication and consumption. With the aid of digital capabilities,

museums are well-positioned to offer an enriched cultural experience that invigorates users' intellectual curiosity about culture.

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