Dual-User Crib Design Based on the SAPAD Model

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To meet the needs of mothers and babies for using baby cribs, this study established a product design process integrating SAPAD theory and the Analytic Hierarchy Process (AHP) from the perspective of maternal-infant lifestyles. Information on mother-baby lifestyles obtained from user studies was analyzed through the SAPAD framework to examine the deep meanings of parenting behaviors and key crib-usage behaviors across different contexts. Cluster analysis and AHP were combined to first generate symmetric clustering matrices identifying meaning clusters, then conduct weight analysis with consistency testing to extract users' core design needs. A core meaning model was constructed to identify corresponding key behaviors and correlates, ultimately yielding five major design modules that translate user requirements into crib design concepts. Design analysis and practice implemented these guidelines, with fuzzy AHP verification confirming the method's effectiveness in guiding crib design. This approach provides an efficient user-centered model for functional modularization in baby cribs and other multi-user products, effectively resolving demand transformation and functional division challenges in multi-user product design.

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INTRODUCTION

With evolving consumption concepts and transformations in infant care needs, contemporary mother-baby groups prioritize personal well-being and scientific childcare more than traditional childcare approaches. Demand for maternal-infant products and services is diversifying, with growing pursuit of premium experiences and substantial market potential for high-end infant care products. In the competitive baby crib market, comprehensive user research constitutes the critical foundation for design innovation and product success. Product design is significantly influenced by lifestyle evolution, making development from maternal-infant lifestyle perspectives essential for enhancing user experience (Jabbar *et al*. 2019). Lifestyle represents a comprehensive manifestation of daily interests, concepts, behavioral tendencies, and characteristics of individuals or groups. A reciprocal relationship exists between lifestyle and product design: lifestyle changes drive product iteration and updating, while product innovations correspondingly influence lifestyles (Zhang 2023). Consequently, profound understanding of lifestyle transitions is crucial for infant product design.

The concept of lifestyle was first introduced by American psychologist Alfred Eckler in 1927, who maintained that lifestyle represents a distinctive pattern of living that emerges only when humans occupy specific social and cultural contexts. In 1963, William

Lazer (1963) incorporated lifestyle research into marketing studies, proposing the AIO model whose primary variables are consumers' activities, interests, and expressed opinions. This framework clearly reveals the significance and value of lifestyle research by explaining user actions through psychological trait reflection. It has progressively become one of the most essential tools for identifying market segment demands. Liu's "Lifestyle Form Model" in design science provides a reference framework for transitioning from life forms to product design. This model systematically connects people, needs, behaviors, events, new tools, new methods, and conceptual design while deeply analyzing their logical relationships (Fei 2022). Li and Sun (2018) completed a preliminary exploration of smart pram innovation by studying infant lifestyles and analyzing observational data from six infants' daily living conditions using the semiotic approach of the product architecture design model.

In crib product design, current trends emphasize enhanced humanization, intelligence, and environmental sustainability. Humanized design prioritizes infant and family needs through features such as height-adjustable, disassemblable, and convertible cribs to enhance usability. Cao and Deng (2019) employed computer-aided innovation with TRIZ theory to identify improvement priorities and resolve technical conflicts in growth-adaptable pram design. Intelligent cribs enable app-based control of temperature, humidity, and sound to improve infant sleep quality (Kaittan *et al.* 2020; Hotur *et al.* 2021; Pratap *et al.* 2021). Kim and Cha (2021) surveyed limited professionals and targeted users on smart cradle development, evaluating form, functionality, stability, colors, and finishes for baby communication technology—though constrained by small sample size and insufficient price analysis. Ferrara and Russo (2018) proposed three customized IOT solutions for infants/parents in educational contexts, highlighting intelligent implementation while fostering emotional engagement within everyday aesthetics frameworks. Sustainability advances include natural materials and paint-free processes. Key research areas cover neonatal care, sleep safety (suffocation risks, positioning, fall prevention), sleep difficulties, and patterns—with newborn care linking to incubator design (Arnoldov 1892; Ball *et al.* 2021). Emerging studies explore smart cribs with cry recognition and remote monitoring/soothing *via* cameras.

Infant sleep is initially regulated primarily by intrinsic mechanisms, characterized by prolonged yet fragmented sleep patterns. As infants reach 12 to 16 weeks, circadian rhythms gradually develop. Parental behaviors in sleep care—including sleep habits, bed selection, bedtime routines, and responses to nighttime awakenings—profoundly impact infant sleep architecture and quality. Through household questionnaires, Yin and Xi (2023) found that 29.7% of families required infant care guidance, with particularly significant needs in responsive care and early learning support. Baddock *et al.* (2019) documented physiological and behavioral differences between co-sleeping and independent crib-sleeping infants: increased nighttime awakenings, elevated bed temperatures, extended breastfeeding duration, and variations in sleep architecture, cardiorespiratory control, and stress cortisol responses. Liu *et al.* (2022) investigated sleep patterns in 0 to 35 month-olds *via* regression analysis, identifying that napping practices, co-sleeping, and parental presence during naps correlated with age and breastfeeding status; frequent napping significantly increased nocturnal awakenings. Wang *et al.* (2021) used paired t-tests and Wilcoxon signed-rank tests to compare paraspinal, abdominal, and lumbar erector spinae electromyography in tilted versus flat mattresses, finding elevated trunk muscle activity and abdominal engagement in prone positions on inclined surfaces—potentially increasing fatigue and suffocation risk if infants cannot self-reposition themselves supine.

Consequently, sleep safety demands heightened attention due to infants' underdeveloped physiological systems. Since family sleep practices critically determine infant sleep outcomes, crib design should assist parents in cultivating healthy sleep habits to enhance sleep quality.

This study aimed to combine the product with the living environment, take the family structure as a unit, explore the lifestyle of the new generation of mother and baby users, analyse the forms of living activities and behavioural characteristics by combining qualitative and quantitative research, explore the hidden needs of mother and baby users, and achieve innovation in the construction of baby bedding products. The goal was to obtain a new and more reasonable product architecture and modules to guide the development and design of baby bedding. Through in-depth analysis of the basic characteristics of mothers and babies, as well as detailed research on existing baby crib products, combined with the study of user behaviours generated in the process of mothers' childcare, the study applied the design process established based on the semiotics approach of product architecture design (SAPAD) model to design, and ultimately obtain a crib design. The result is intended to meet the needs of users, in order to provide detailed childcare conditions, to promote the intimacy of mothers and babies, and to soothe the sense of fatigue of the caregiver. In addition, the design of the crib may, to a certain extent, solve the pain points such as babies' unwillingness to sleep in cribs, inconvenient use of cribs, and low usage rate of cribs.

EXPERIMENTAL

With shifting parenting attitudes and consumer behaviors among new-generation child-rearing groups, crib product demands undergo continuous transformation. The study targeted post-90s mothers and families raising infants aged 0 to 3 years, centering on mother-infant lifestyles. User behaviors obtained through preliminary non-participatory observation, user interviews, and expert interviews were summarized and deconstructed. These were analyzed *via* the SAPAD theoretical framework combined with Analytic Hierarchy Process (AHP) to quantify qualitative data, examine deeper meanings of mother-infant interaction behaviors across scenarios, and transform user need elements into crib design concepts. The experimental procedure is illustrated in Fig. 1.

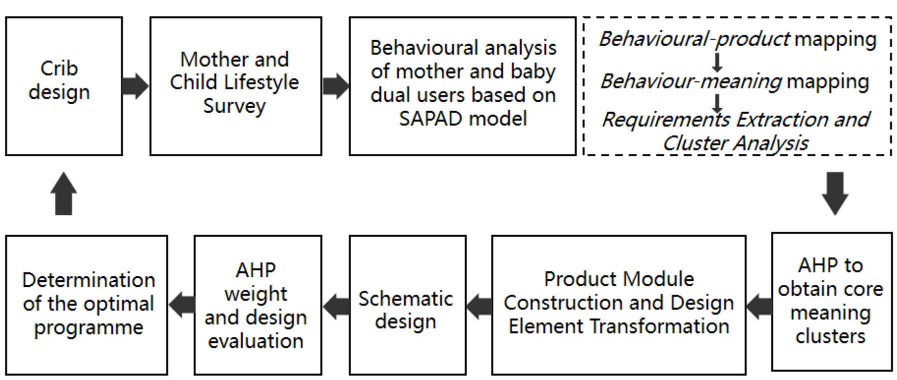

Fig. 1. Experimental process

Behavioral Analysis of Users Based on SAPAD Model

The Semiotic Path for Product Architecture and Design is referred to as the SAPAD model, and human-computer interaction consists of the joint action of user behaviour and the product; therefore, it is also necessary to study the behavioural correlates and key correlates. User behaviours obtained through preliminary non-participatory observation, user interviews, and expert interviews were summarized and decomposed. These were constructed through the SAPAS theoretical framework combined with AHP to quantify and analyse qualitative issues, study the deeper meanings of mother-infant interaction behaviours in different scenarios, and transform the elements of user needs to the concept of baby crib design.

Behavioral Analysis of Users Based on SAPAD Model

The SAPAD model first decomposes user behaviours into tasks and subtasks. Then it maps the objects involved to corresponding behaviours to complete behaviour-product mapping (Wang 2022). Based on the SAPAD theoretical framework, analysis of interview and non-participatory observation data revealed that typical mother-infant daily activities are classifiable into five domains: (A) Sleep care, (B) Feeding, (C) Parent-child interaction, (D) Daily care, (E) Health monitoring. By systematizing relationships between infant/maternal behaviours, environments, tasks, subtasks, and behavioral correlates across these domains, the activities were subdivided into 53 specific sub-actions, as shown in Table 1.

According to SAPAD mapping theory, the environments involved in tasks were further correlated with corresponding objects to complete user behaviour-product mapping analysis, as shown in Table 2.

User Behaviour-Meaning Mapping Analysis

According to the SAPAD model, the mapping continuum of behavioral meanings comprised six levels: physical, discursive-constructive, semantic, experiential, discursive, and pragmatic. Through participatory observation and in-depth interviews, analysis of the 53 subtasks revealed that mother's daily caring constitutes multi-product, multi-user collaborative behavior. Consequently, user behaviors were categorized into three meaning levels: experiential, semantic, and pragmatic. The experiential level emphasizes skills and sensory experiences during human-product interaction (Lu *et al.* 2023); the semantic level denotes meanings conveyed by mother-infant-product interactions, encompassing affective experiences; and the pragmatic level focuses on user-stakeholder interactions and information dissemination behaviors (Wang 2018).

After analyzing the detailed table derived from the interpretation of user behaviors, the volume of information was found to be relatively large and disorganized for the purpose of subsequent product construction. Therefore, the mothers' daily infant care behaviors were screened and deduplicated, and those with higher relevance to crib-related behaviors were selected. These preliminarily screened behaviors were then interpreted using the expert evaluation method. Experienced product designers and graduate students majoring in industrial design were invited to interpret the user behaviors. The infant care behaviors were subsequently simplified and clustered to derive the core meanings, thereby completing the construction of the final meaning framework. After having achieved an in-depth understanding of the meaning of each level, the mapping relationship between the mother's daily baby care behaviors and the meaning obtained by simplifying the content of each level corresponding to each behavior is shown in Table 3.

Table 1. Decomposition and Coding of Mother-Infant Behaviour

Activity	Task	Subtask
A Sleeping Care	**A1** Pre-Sleep	**A1-1** Sorting out crib clutter **A1-2** Help baby to urinate and change nappies **A1-3** Mum picks up baby and walks back and forth **A1-4** Mum puts baby in pram and pushes **A1-5** Rocking baby to sleep **A1-6** Tap baby to get them to sleep quickly **A1-7** Mum plays or hums soft music **A1-8** When the baby is asleep mum puts the baby back in the crib, sets up the enclosure and lets the baby go back to sleep **A1-9** Parents put toys instead of parental arms or patting to give babies a sense of security and enable them to sleep independently
	A2 Sleeping	**A2-1**Mum wakes up frequently to check if baby needs to be tucked in **A2-2** The baby wakes up easily and cries a lot, and the mother will pat the baby in response to the baby **A2-3** Mum will assist baby to adjust the sleeping position every now and then to prevent the head shape from being affected by keeping the same position for a long time
	A3 Wake Up	**A3-1** The baby cries frequently during the second half of the night, and the mother struggles to switch on the night light to determine the cause of the baby's nighttime cries **A3-2** Judging that it is a sign of baby's hunger, the mother carries the baby to herself and lies on her side to breastfeed **A3-3** Judgement is the baby waking up mother gently pat to sleep **A3-4** Judging that it's a medical condition, mum touches baby's forehead to check for fever **A3-5** Mum checks nappies for wetness to determine cause of night crying **A3-6** Mum needs to take care of dressing baby when they are out of bed to prevent colds
B Feeding and Lactation	**B1** Formula Feeding	**B1-1** When baby cries, mum first checks the time to confirm infant hunger signals **B1-2** Mum placing baby safely on a feeding mat in the crib **B1-3** Quickly prepare breastfeeding equipment and make milk powder **B1-4** Mum lying on her side next to the crib **B1-5** Hold the bottle firmly in your hand and start feeding the baby
	B2 Complementary Feeding	**B2-1** Mum puts baby in baby dining chair **B2-2** Talk to baby constantly to calm his or her anxieties **B2-3** Prepare complementary food **B2-4** Mum sits across from baby and feeds with a spoon
C Parent-child	**C1** Tactile Training	**C1-1** Mum washes her hands first and she places the baby on the nappy table with a towel **C1-2** Mum pours massage oil or lotion into her hands, rubs to warm and then applies it to the baby and

Interaction		starts massaging.
	C2 Grip and Leg Strength Training	**C2-1** Mum places baby flat on the gym frame **C2-2** Baby can reach out, grasp and stomp on the musical instrument, exercising baby's eye function and leg strength **C2-3** Mum is always on hand to keep an eye on the baby's safety and to avoid the baby swallowing the toys
	C3 Crawling Training	**C3-1** Mum arranges crawling mats and playpen **C3-2** Mum holds toys in front to attract baby to crawl freely on the crawling mat
	C4 Emotional Exchange	**C4-1** Mum cuddles and kisses the baby, always paying attention to changes in the baby's expression **C4-2** Mum puts the baby into the rocking chair and faces the baby to guide the baby to learn pronunciation through singing, storytelling and communicating with the baby
D Daily Care	**D1** Washing	**D1-1** Put on the bath water and prepare the bath **D1-2** Hold the baby and wash he/she **D1-3** Wrap baby in a bath towel and dry on a nappy table, apply lotion to baby
	D2 Change Nappies	**D2-1** Mum places baby flat on the nappy table **D2-2** Unwrap the nappy to check the situation **D2-3** Prepare a basin of warm water and bring it to the bedroom **D2-4** Mum wipes baby's bottom with warm water and a towel, applies emollient oil and changes baby's nappy to a clean one
	D3 Wear Clothes	**D3-1** Check the weather to match your baby's warm and comfortable clothes. **D3-2** Changing baby's clothes in bed
	D4 Sunbathe	**D4-1** Mum puts baby in the crib and positions the enclosure **D4-2** Moving the crib to the balcony exposes baby to fresh air and sunlight **D4-3** Lowering the crib curtain to cover the baby's head
E Health Monitoring	**E1** Growth Condition Monitoring	**E1-1** Mum holds baby to measure weight and calculate baby's weight **E1-2** The baby lies flat on the crib and the mother puts the baby's legs flat to measure the length of the body **E1-3** Mum takes the temperature gently with an ear thermometer **E1-4** Measure the circumference of baby's head using a soft ruler **E1-5** The mother enter the measurement results into the mobile phone software, with the help of the software to automatically generate the baby's growth curve, observe the curve changes
	E2 Observation Records	**E2-1** Mum spends a lot of time each night before bedtime recording observations of her baby's sleep, eating, elimination, physical activity and movement, as well as emotional and social development on a form

Table 2. User Behavior-Product Mapping Analysis

Activity	Environment	Task	Subtask	Behavior-related Artifacts
A	Bedroom	A1	A1-1, A1-2	Nappies, nappy tables, storage baskets
			A1-3, A1-4, A1-5, A1-6 , A1-7	Prams, soothing toys
			A1-8, A1-9	Crib, safety enclosures, soothing toys
		A2	A2-1,A2-2,A2-3	Crib, bedding
		A3	A3-1,A3-2,A3-3,A3-4,A3-5	Crib, adult bed, night light
			A3-6	Clothes
B	Bedroom	B1	B1-1,B1-2,B1-3,B1-4,B1-5	Clock, crib, feeding mat, bottle
	Living Room	B2	B2-1,B2-2,B2-3,B2-4	Infant dining chairs, cutlery
C	Bedroom	C1	C1-1,C1-2	Nappy table, towels, skincare product
		C2	C2-1,C2-2,C2-3	Crib, gym frames, toys
	Living Room	C3	C3-1,C3-2	Toys, crawling mats, playpen
	-	C4	C4-1,C4-2	Rocking chair, storybook, music player
D	Bathroom	D1	D1-1,D1-2,D1-3	Bath tub, toiletries, nappy table, skincare products
	Bedroom	D2	D2-1,D2-2,D2-3,D2-4	Nappy table, nappies, wash basin, towels
		D3	D3-1,D3-2	Mobile App, crib, clothing
	Balcony	D4	D4-1,D4-2,D4-3	Crib, side rails, curtains
E	Bedroom	E1	E1-1,E1-2,E1-3,E1-4,E1-5	Nappies, crib, scale, soft ruler, mobile app
		E2	E2-1	Paper form

Table 3. Mother's Daily Care of Infant Behavior and Meaning Mapping Relationship

Subtask	Meaning Level		
	Experiential Level	**Semantic Level**	**Pragmatic Level**
A1-1	Simplified Storage Steps	Focus on sleep safety	With storage space
A1-3	Soothing the baby	Tired arms	Wrap-around feeling
A1-5	Play white noise	Impatient with long bedtimes	Ability to play lullabies
A1-6	Shaking the pram	Tired of pushing	Can be shaken and stable
A1-7	Prams can't be flattened	Hard to move.	Reduced movement of the baby
A1-9	Protect against knocks	Worried about the baby getting hurt	Rounded lines and soft materials
A2-1	Check the quilt	Worried about sleeping temperature	Ability to remotely monitor sleep temperature
A2-2	Respond baby timely	No personal time	Detect and respond to crying timely
A2-3	Adjustable headrest to adjust sleeping position	Convenient and easy to adjust the sleeping position	Ability to monitor and correct sleeping position
A3-1	Fumbling in the dark to turn on the night light	Frequent night wakings lead to tiredness in mums	Determining the cause of crying
A3-3	Help baby to keep sleeping	Wake up sleepy at night	Able to assist baby to keep sleeping
A3-4	Take temperature	Worried about the baby getting sick	Ability to monitor baby's temperature
A3-5	Checking nappy moisture	Concerns about nappy cleanliness	Detecting nappy condition
B1-1,B1-3, B2-3	Regular feeding	Focus on balanced nutrition	Able to plan meals
B1-4	15° slope to prevent choking	Preventing baby from choking	Prevention of choking risk
C2-1,C2-2, C3-2	Training with toys	Have fun interacting	Interactive game function
D2-1	Bend over when using	Focus on body hygiene	Adjustable height
D3-1	Dress for the weather	Caring for the baby	Ability to intelligently recommend wearing
D4-1	Installation of fencing on both sides	Worried about the baby falling	Easy and secure fence installation
D4-3	Direct sunlight on the face	Conveniently shielded from light	Ability to create a dimly lit environment
E1-1,E1-2, E1-3,E1-4	Measurement of body, signs data	Focus on healthy growth	Real-time monitoring and analysis of baby's health
E1-5,E2-1	Record and analyse data	Spend a lot of time recording	Able to quickly record baby's growth data

User Requirement Element Extraction and Cluster Analysis

The meanings of maternal daily infant care behaviors have been clarified at experiential, semantic, and pragmatic levels. To further explore relationships between mothers-cribs, babies-cribs, and mothers-babies, correlations between meanings were analyzed using Boolean logic algorithms. These algorithms clustered meanings in a hierarchical manner (experiential → semantic → pragmatic), merging strongly correlated same-level meanings to identify behavioral correlations and tendencies. For clear visualization of meaning clusters, a four-color gradient scheme (light-to-dark) was implemented with numerical tiers: 3=strong correlation, 2= moderate correlation, 1=weak correlation, 0=no correlation. The output generated symmetric clustering matrices (Yang and He 2023).

The experiential level reflects users' cognition of products or environments through prior experience, embodying human-artifact relationships. Cluster analysis identified five meaning clusters for maternal infant care behaviors at this level (Fig. 2): (1) Operational Convenience: Simplified storage steps, Non-flattening strollers, Crib bending posture, Dual-side rail installation, Toy-assisted training; (2) Standard Soothing Protocol: Embrace comforting, White noise emission, Stroller rocking, Sleep transition assistance; (3) Safety Assurance: Roll impact protection, Blanket adjustment, Prompt infant response; (4) Functional Manipulability: Headrest sleep-position adjustment, 15° incline anti-aspiration, Nightlight tactile activation, Sunlight exposure avoidance; and (5) Developmental Routine: Scheduled feeding, Diaper humidity checks, Temperature measurement, Weather-adaptive dressing, Biometric tracking, Growth data analysis.

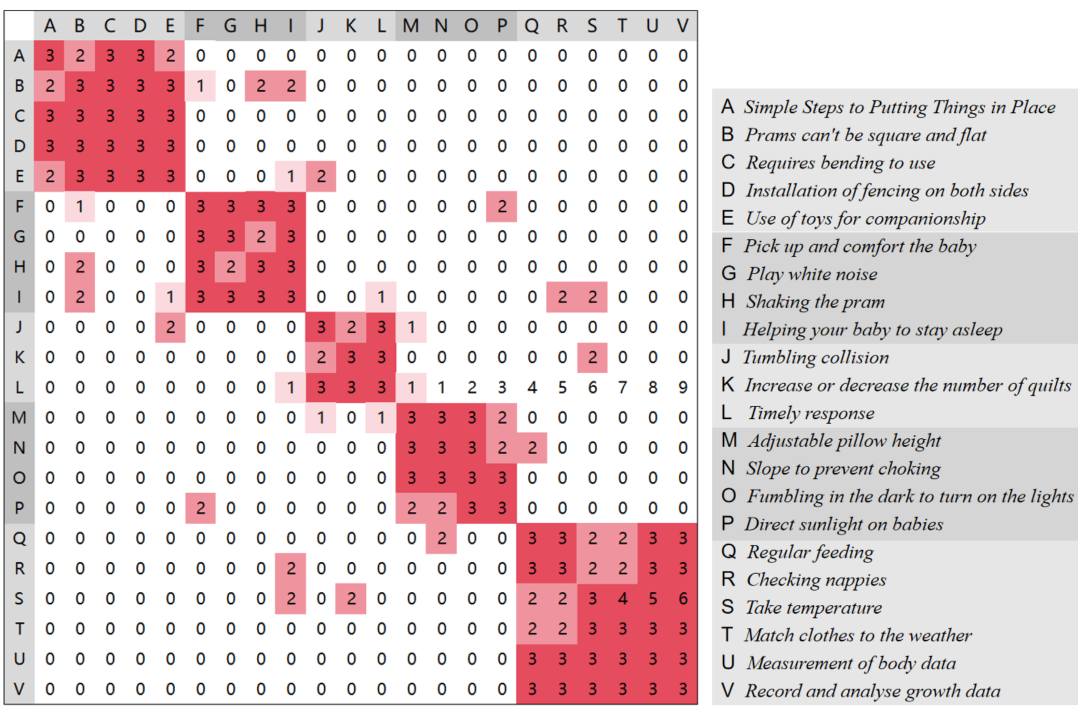

Fig. 2. Empirical layer clustering analysis

The semantic level emphasizes meanings conveyed through mother-infant-product interactions, encompassing users' emotional experiences. Its meaning clusters represent emotional demands toward interactive products. Cluster analysis yielded five semantic-level meaning clusters for maternal care behaviors (Fig. 3): (1) Safety Anxiety: Sleep temperature concerns, Injury prevention, Fall risk vigilance, Sleep safety prioritization, Aspiration prevention; (2) Developmental Wellness: Illness prevention, Hygiene maintenance, Healthy growth promotion, Nutritional balance; (3) Soothing Impatience: Protracted soothing duration, Repetitive motion fatigue, Personal time deprivation, Physical strain during repositioning, Arm fatigue from holding; (4) Caregiver Exhaustion: Nighttime accessibility issues, Frequent waking fatigue, Time-intensive documentation, Laborious sleep positioning, Cumbersome light-blocking procedures; and (5) Bonding Enjoyment: Positive interaction, Auditory engagement, Affectionate nurturing.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
A	3	2	2	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
D	3	3	3	3	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	3	3	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	2	0	0	1	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	1
G	0	0	0	1	0	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	3	3	3	3	0	0	0	0	0	0	0	0	0	2	0	0	0
I	0	0	0	0	0	3	2	3	3	0	0	0	0	0	0	0	0	0	2	0	0	0
J	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
M	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	3	3	3	3	3	2	1	0	0	0	0	0	0
O	0	0	0	0	0	0	0	0	0	1	1	1	1	2	3	3	3	3	3	0	0	0
P	0	0	0	0	0	0	0	0	0	1	1	1	1	1	3	3	3	3	3	0	0	0
Q	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0	0
R	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0	0
S	0	0	0	0	0	0	0	2	2	0	0	0	0	0	3	3	3	3	3	0	0	0
T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
V	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3

A *Worried about sleeping temperature*
B *Prams can't be square and flat*
C *Worried about the baby falling*
D *Focus on sleep safety*
E *Preventing baby from choking*
F *Worried about the baby getting sick*
G *Focus on cleanliness and hygiene*
H *Focus on healthy growth*
I *Focus on balanced nutrition*
J *Impatient with long bedtimes*
K *Fatigue from prolonged shaking*
L *No personal time*
M *Hard to move*
N *Arm pain*
O *Inconvenient to get up at nigh*
P *Frequent night wakings*
Q *Spend a lot of time recording*
R *Difficulty in adjusting sleeping position*
S *Cumbersome steps to block out light*
T *Have fun interacting*
U *Attention grabbing with music*
V *Caring for the baby*

Fig. 3. Semantic layer clustering analysis

The pragmatic level emphasizes meanings conveyed through mother-infant-product interactions, encompassing users' emotional experiences. Its meaning clusters represent personal emotional demands toward interactive products. Cluster analysis yielded five semantic-level meaning clusters for maternal care behaviors (Fig. 4): (1) Safety Concerns: Sleep temperature monitoring, Injury prevention, Fall risk vigilance, Sleep safety prioritization, Aspiration prevention; (2) Growth Wellness: Illness prevention, Hygiene maintenance, Healthy development, Nutritional balance; (3) Soothing Frustration: Protracted soothing duration, Repetitive motion fatigue, Personal time deprivation, Laborious repositioning, Arm strain from holding; (4) Caregiver Burden: Nighttime accessibility challenges, Frequent waking exhaustion, Time-intensive documentation, Laborious sleep positioning, Cumbersome light-blocking procedures; and (5) Bonding Positivity: Enjoyable interaction, Auditory engagement through music, Affectionate nurturing.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
A	3	2	2	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
D	3	3	3	3	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	3	3	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	2	0	0	1	2	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	1
G	0	0	0	1	0	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	3	3	3	3	0	0	0	0	0	0	0	0	0	2	0	0	0
I	0	0	0	0	0	3	2	3	3	0	0	0	0	0	0	0	0	0	2	0	0	0
J	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
M	0	0	0	0	0	0	0	0	0	3	3	3	3	3	1	1	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	3	3	3	3	3	2	1	0	0	0	0	0	0
O	0	0	0	0	0	0	0	0	0	1	1	1	1	2	3	3	3	3	3	0	0	0
P	0	0	0	0	0	0	0	0	0	1	1	1	1	1	3	3	3	3	3	0	0	0
Q	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0	0
R	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0	0
S	0	0	0	0	0	0	0	2	2	0	0	0	0	0	3	3	3	3	3	0	0	0
T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
V	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3

A *Worried about sleeping temperature*
B *Prams can't be square and flat*
C *Worried about the baby falling*
D *Focus on sleep safety*
E *Preventing baby from choking*
F *Worried about the baby getting sick*
G *Focus on cleanliness and hygiene*
H *Focus on healthy growth*
I *Focus on balanced nutrition*
J *Impatient with long bedtimes*
K *Fatigue from prolonged shaking*
L *No personal time*
M *Hard to move*
N *Arm pain*
O *Inconvenient to get up at nigh*
P *Frequent night wakings*
Q *Spend a lot of time recording*
R *Difficulty in adjusting sleeping position*
S *Cumbersome steps to block out light*
T *Have fun interacting*
U *Attention grabbing with music*
V *Caring for the baby*

Fig. 4. Pragmatic layer clustering analysis

AHP-Based Cluster Analysis of the Core Meaning of Baby-Care Behaviour

Through Boolean logic correlation matrix analysis, meaning clusters of mothers' baby-care behaviors were obtained across experiential, semantic, and pragmatic levels. To derive core meaning clusters, this study employed Analytic Hierarchy Process (AHP) for weight analysis of clustered meanings. Meaning clusters and their constituent meanings were designated as criterion and sub-criterion layers respectively. Weight analysis identified higher-weighted indicators as core meaning clusters within each semantic level.

Cluster Analysis of Core Meaning at the Empirical Level

Using experiential-level maternal care behavior meanings as the target layer, a hierarchical structure model was established with the five meaning clusters derived from cluster analysis serving as the criterion layer, as shown in Fig. 5.

For the established hierarchical structure model, 10 product designers, 15 crib users, and 5 infant growth experts were recruited through expert evaluation methods to form a 30-member assessment team. Using the 1-9 scale method, pairwise comparisons were performed for the five criterion layer indicators, assigning importance values to construct the judgment matrix (Table 4). The criterion layer judgment matrix underwent normalization via the sum-and-product method, yielding weight values for these indicators (Table 5).

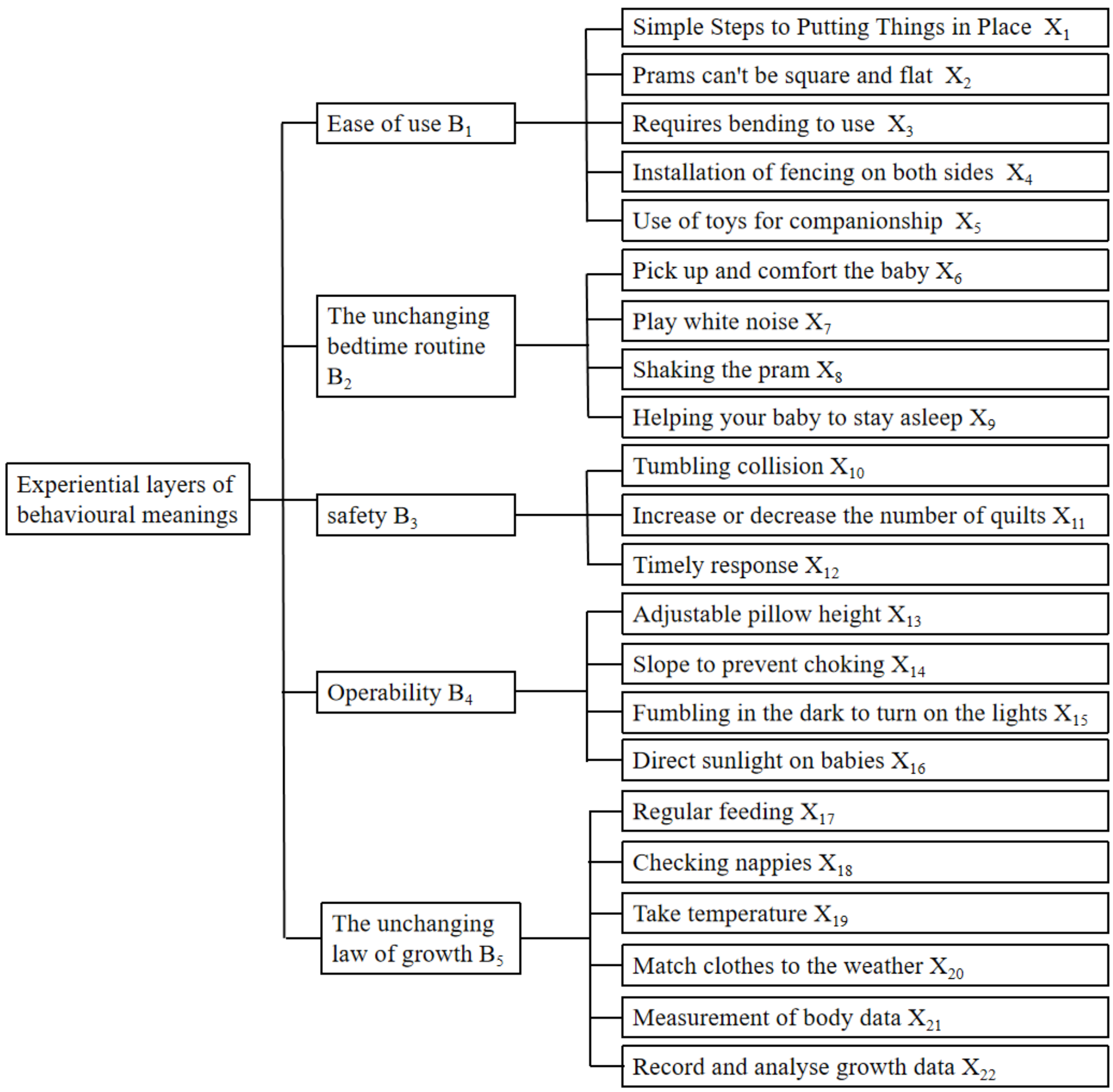

Fig. 5. Hierarchical model of empirical layer

Table 4. The Criterion Layer Judgment Matrix

B	B1	B2	B3	B4	B5
B1	1	4	1/5	1/2	7
B2	1/4	1	1/7	1/3	3
B3	5	7	1	6	9
B4	2	3	1/6	1	5
B5	1/7	1/3	1/9	1/5	1

Table 5. The Criterion Layer Index Weight

B	B1	B2	B3	B4	B5	Weight
B1	0.1191	0.2609	0.1234	0.0622	0.2800	0.169
B2	0.0298	0.0652	0.0881	0.0415	0.1200	0.069
B3	0.5957	0.4565	0.6170	0.7469	0.3600	0.555
B4	0.2383	0.1957	0.1028	0.1245	0.2000	0.172
B5	0.0170	0.0217	0.0686	0.0249	0.0400	0.034

The consistency test index CR was calculated as 0.089. With CR < 0.1, the judgment matrix meets validity criteria, confirming high result confidence (Table 6).

Table 6. Summary of the Consistency Test Results

λ_{max}	CI	RI	CR	Consistency Test Results
5.398	0.100	1.120	0.089	Pass

Table 7. Summary of the Results of the Guideline Layer Consistency Test

	λ_{max}	CI	RI	CR	Consistency Test Results
B1	5.171	0.043	1.12	0.038	Pass
B2	4.015	0.005	0.89	0.005	Pass
B3	3.066	0.033	0.52	0.063	Pass
B4	4.185	0.062	0.89	0.069	Pass
B5	6.518	0.104	1.26	0.082	Pass

Similarly, weight analysis was conducted for each sub-criterion layer factor. All judgment matrices demonstrated consistency test indices (CR) below 0.1, confirming indicator layer consistency validation as shown in Table 7. To enable unified comparison of specific indicators during subsequent crib design practices—clarifying primary-secondary relationships and facilitating targeted solution evaluation—composite weights were calculated across sub-criterion layers. The criterion layer weights were multiplied by corresponding sub-criterion weights to derive composite weight values. Experiential-level maternal care behavior weights are presented in Table 8.

Table 8. The Empirical Layer Behavioral Meaning Weight

Criterion Layer	Indicator Layer		Comprehensive Weight
Weight	Factors	Weight	
B1 0.1691	X1	0.0374	0.0063
	X2	0.4360	0.0300
	X3	0.1548	0.0860
	X4	0.3012	0.0519
	X5	0.0706	0.0024
B2 0.0689	X6	0.4824	0.0332
	X7	0.0883	0.0061
	X8	0.1575	0.0109
	X9	0.2718	0.0187
B3 0.5552	X10	0.7235	0.4017
	X11	0.0833	0.0463
	X12	0.1923	0.1073
B4 0.1723	X13	0.1143	0.0197
	X14	0.6157	0.1061
	X15	0.0489	0.0084
	X16	0.2212	0.0381
B5 0.0344	X17	0.4136	0.0142
	X18	0.1317	0.0045
	X19	0.2750	0.0095
	X20	0.0340	0.0012
	X21	0.0883	0.0030
	X22	0.0575	0.0020

Analysis of experiential-level maternal care behavior weights revealed that the Safety Criterion held the highest weight value, followed by Operational Convenience and Functional Manipulability. Consequently, three core meaning clusters emerged: Safety, Operational Convenience, and Functional Manipulability. Product design solutions must prioritize these requirements.

Cluster Analysis of Core Meaning at the Empirical Level

Applying the core meaning cluster analysis methodology from the experiential level to semantic and pragmatic levels yielded the semantic-level hierarchical structure model (Fig. 6) and behavior weights (Table 9). All criterion layer CR values passed consistency validation (CR < 0.1), confirming result validity (Table 10).

Table 9. The Semantic Layer Behavioral Meaning Weight

Criterion Layer	Indicator Layer		Comprehensive Weight
Weight	Factors	Weight	
B1 0.0651	X1	0.0358	0.0023
	X2	0.2953	0.0192
	X3	0.4515	0.0294
	X4	0.0722	0.0047
	X5	0.1454	0.0095
B2 0.2916	X6	0.0569	0.0166
	X7	0.2634	0.0768
	X8	0.5579	0.1627
	X9	0.1219	0.0355
B3 0.4627	X10	0.5005	0.2316
	X11	0.2529	0.1170
	X12	0.1190	0.0551
	X13	0.0694	0.0321
	X14	0.0581	0.0269
B4 0.0428	X15	0.0350	0.0015
	X16	0.5066	0.0217
	X17	0.0719	0.0031
	X18	0.1233	0.0053
	X19	0.2631	0.0113
B5 0.1379	X20	0.1932	0.0266
	X21	0.7235	0.0997
	X22	0.0833	0.0115

Weight analysis was conducted for pragmatic-level meanings, constructing hierarchical structure models and judgment matrices. The pragmatic-level hierarchical structure model is shown in Fig. 7, with corresponding maternal care behavior weights presented in Table 10. All criterion layer CR values passed consistency validation (CR < 0.1), confirming result validity.

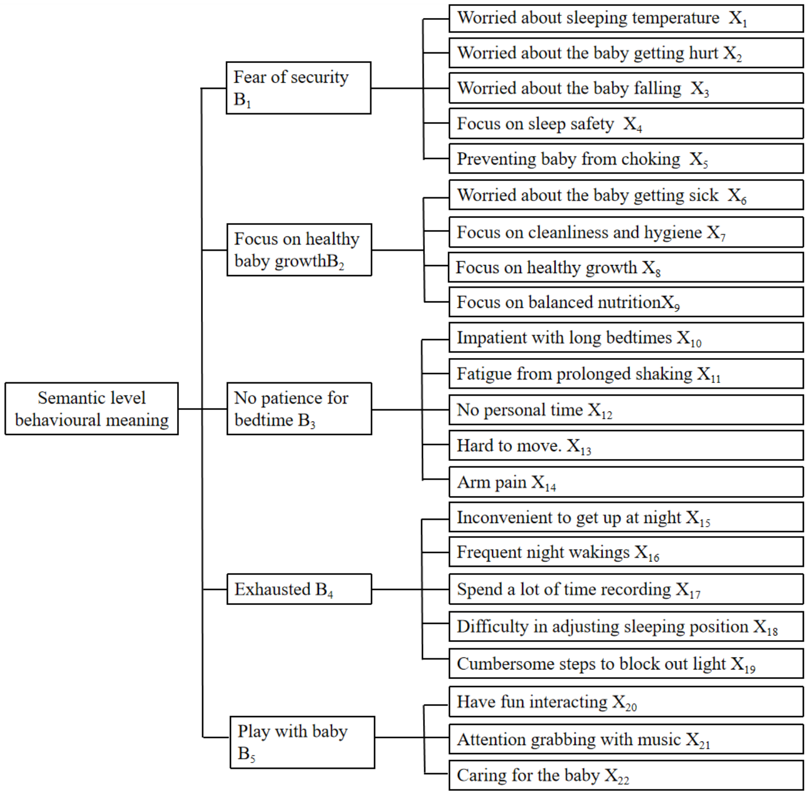

Fig. 6. Hierarchical model of semantic layer

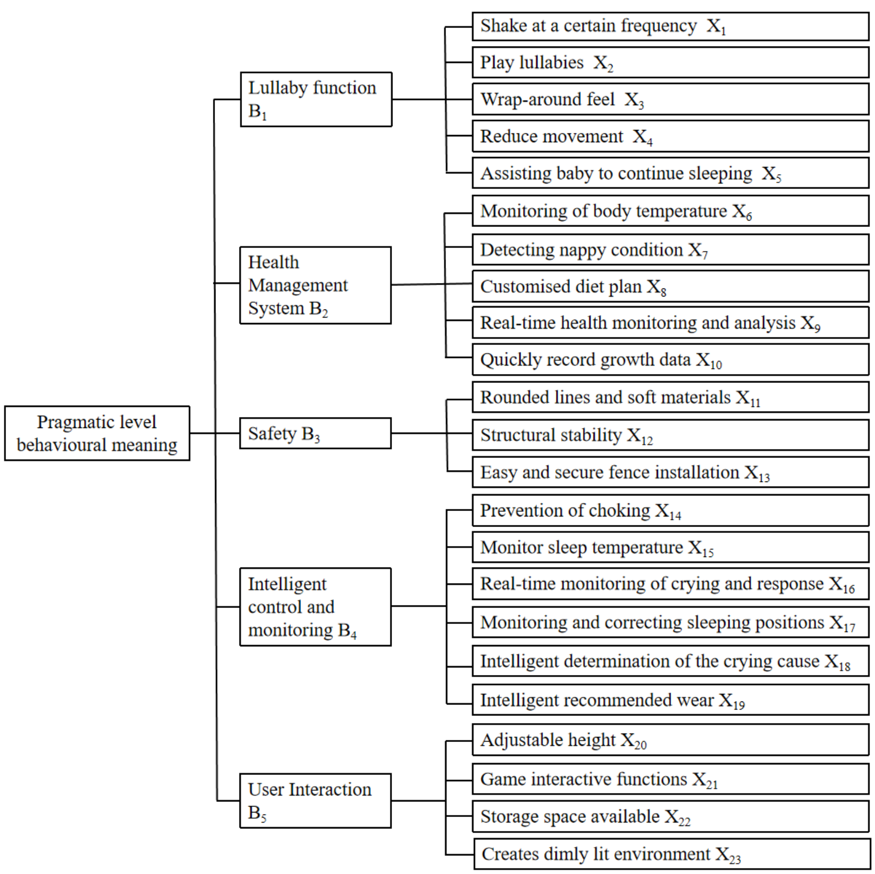

Fig. 7. Hierarchical model of pragmatic layer

Table 10. The Pragmatic Layer Behavioral Meaning Weight

Criterion Layer	Indicator Layer		Comprehensive Weight
Weight	Factors	Weight	
B1 0.0678	X1	0.4975	0.0337
	X2	0.0487	0.0033
	X3	0.2640	0.0179
	X4	0.1171	0.0079
	X5	0.0727	0.0049
B2 0.1344	X6	0.1253	0.0168
	X7	0.0866	0.0116
	X8	0.0509	0.0068
	X9	0.4678	0.0628
	X10	0.2694	0.0362
B3 0.5028	X11	0.1062	0.0534
	X12	0.6334	0.3185
	X13	0.2605	0.1310
B4 0.2602	X14	0.4128	0.1074
	X15	0.1540	0.0401
	X16	0.0904	0.0235
	X17	0.2542	0.0662
	X18	0.0547	0.0142
	X19	0.0339	0.0088
B5 0.0348	X20	0.5579	0.0194
	X21	0.2634	0.0092
	X22	0.0569	0.0020
	X23	0.1219	0.004

RESULTS AND DISCUSSION

Module Construction and Design Element Translation for Baby Crib Products Based on Meaning Models

Previous research has completed mother-infant care behavior-to-artifact mappings, behavior-to-meaning mappings, and core meaning cluster extraction, yielding experiential-level core clusters (safety, operational convenience, functional manipulability), semantic-level core clusters (soothing Frustration, growth wellness, bonding positivity), and pragmatic-level core clusters (safety assurance, intelligent monitoring & alerts, health management systems). Identical meanings may manifest across different behaviors, while singular behaviors may embody multiple meanings, necessitating extraction of meaning commonalities and analysis of meaning correlations to construct core cluster relationships. By examining interconnections among pragmatic-, experiential-, and semantic-level core clusters, a meaning model for maternal daily care behaviors was established as shown in Fig. 8.

Through the “meaning-based product construction” framework within the SAPAD model, a re-mapping analysis of “core meaning clusters to products” was conducted to identify key artifacts corresponding to behaviors, ultimately yielding the mapped relationships among core meaning clusters, key behaviors, key artifacts, and design elements as presented in Table 11.

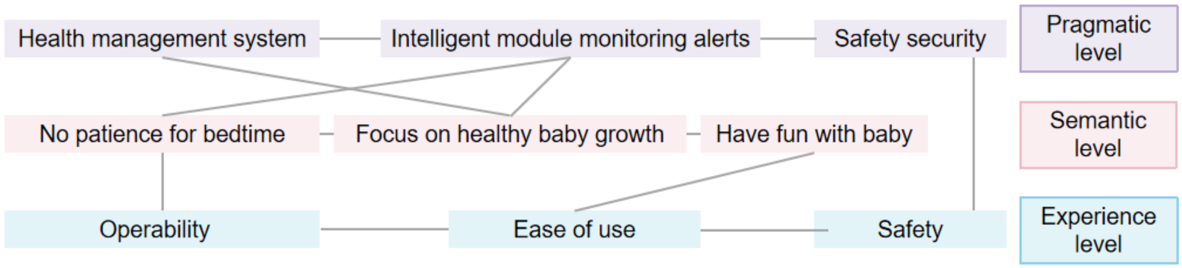

Fig. 8. Meaning model of mother's daily care of baby behavior

Table 11. Mapping Analysis of the Core Significance Cluster-Object-Design Elements of the Crib

Core Meaning Clusters	Key Behaviors	Correlated Artifacts	Design Element Translation
Impatient Sleeping, Operability, Intelligent control and monitoring alerts	A1-3,A1-5, A1-6,D4-3	Wheels, rocking structure, microphone, speakers, drapery	Shake and soothe Music playback Light control Wraparound feel
Safety, Security, Intelligent control and monitoring alerts	A1-4,A1-7, A1-9,A2-1, A2-2,A2-3	Prams, enclosures, bed stops, fall protection, cry detection devices, qualitative pillows, breastfeeding mats	Structural safety Material safety Real-time monitoring Risk warning Body support
Health management system, Focusing on the healthy development of the baby	A3-3,B1-1, D3-1,E1-1, E1-2,E1-3, E1-1,E1-5, E2-1	Scales, tape measure, thermometer, clock, clothing, recording forms	Physical signs monitoring Growth monitoring Sleep quality monitoring Feedback processing Regularity of life
Convenience and ease of use, Accompanied by baby's playfulness	A3-1,C2-1, C2-2,C4-2	Night light, fitness rack, music player	Easy to get up at night Voice Interaction Game Interaction Remote operation Aesthetically pleasing
Ease of use, Operability	A1-1,D2-1, D4-1	Locker, nappy table, enclosure, wheels	Adjustable Convenient storage Can be disassembled and assembled

The pragmatic level maps users' functional expectations for baby cribs, necessitating ensured usability; the experiential level maps operational requirements, demanding optimized ease-of-use and operational efficiency; the semantic level maps interactive experiences, requiring positive emotional feedback and enhanced user satisfaction during operation.

By contextualising the product design, the cluster reinterpreted the core meanings of a mother's daily behaviour in caring for her baby using baby bedding products. Six core clusters were translated into product modules, yielding five redesigned modules centered on semantic-experiential-pragmatic integration: Intelligent Sleep Module, Safety & Monitoring Module, Health Management Module, Interactive Experience Module, and Growth Adaptation Module (Fig. 9). Corresponding crib design elements are shown in Fig. 10, with primary design directions including:

(1) Intelligent Sleep Module: Rocking mechanism, audio playback, and light control for sleep environment optimization; structural envelopment for infant security.

(2) Safety & Monitoring Module: Structural/material safety protocols, real-time surveillance, anomaly alerts, and posture-adjusting supports for aspiration prevention.

(3) Health Management Module: Vital sign monitoring (heart rate/temperature), growth tracking (height/weight), sleep quality analysis, data feedback systems, and routine development (feeding/diapering/sleep).

(4) Interactive Experience Module: Voice interaction, play activities, mobile-integrated remote operation, aesthetic formgiving, and nighttime accessibility.

(5) Growth Adaptation Module: Adjustable configurations, modular disassembly, and compact storage.

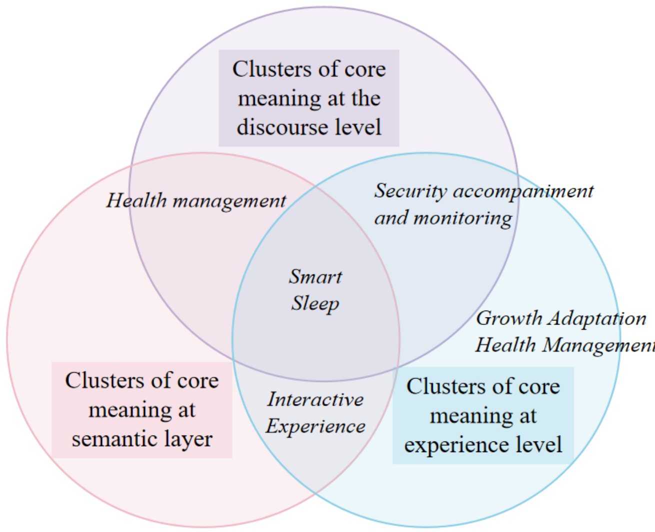

Fig. 9. Crib product module construction

Discussion

This experimental employed in-depth interviews and non-participatory observation to investigate maternal-infant lifestyles, delineating contemporary parenting patterns while summarizing characteristic caregiving activities and behaviors. Subsequent application of the SAPAD methodology facilitated behavioral meaning construction and mapping analysis, beginning with artifact-behavior mapping of caregiving objects. Meanings underlying experiential, semantic, and constructive-level behaviors were extracted, simplified, and clustered to derive meaning clusters. Quantitative weight analysis *via* Analytic Hierarchy Process (AHP) identified core meaning clusters, establishing behavior-core cluster mappings. This completed the behavior-meaning-artifact mapping chain, enabling product module construction and design element translation to propose concrete design directions, thereby establishing the foundation for SAPAD-based crib design strategies.

Crib design solution

Synthesizing the preceding research, the subsequent crib design focus can be definitively established. This enables analysis of design positioning and formulation of design strategies to derive the final solution, followed by feasibility verification to confirm result achievability. Guided by experimentally derived design positioning, subsequent design practices proceed with precision. The crib design framework now possesses defined parameters, serving as the basis for generating the design solution shown in Fig. 11.

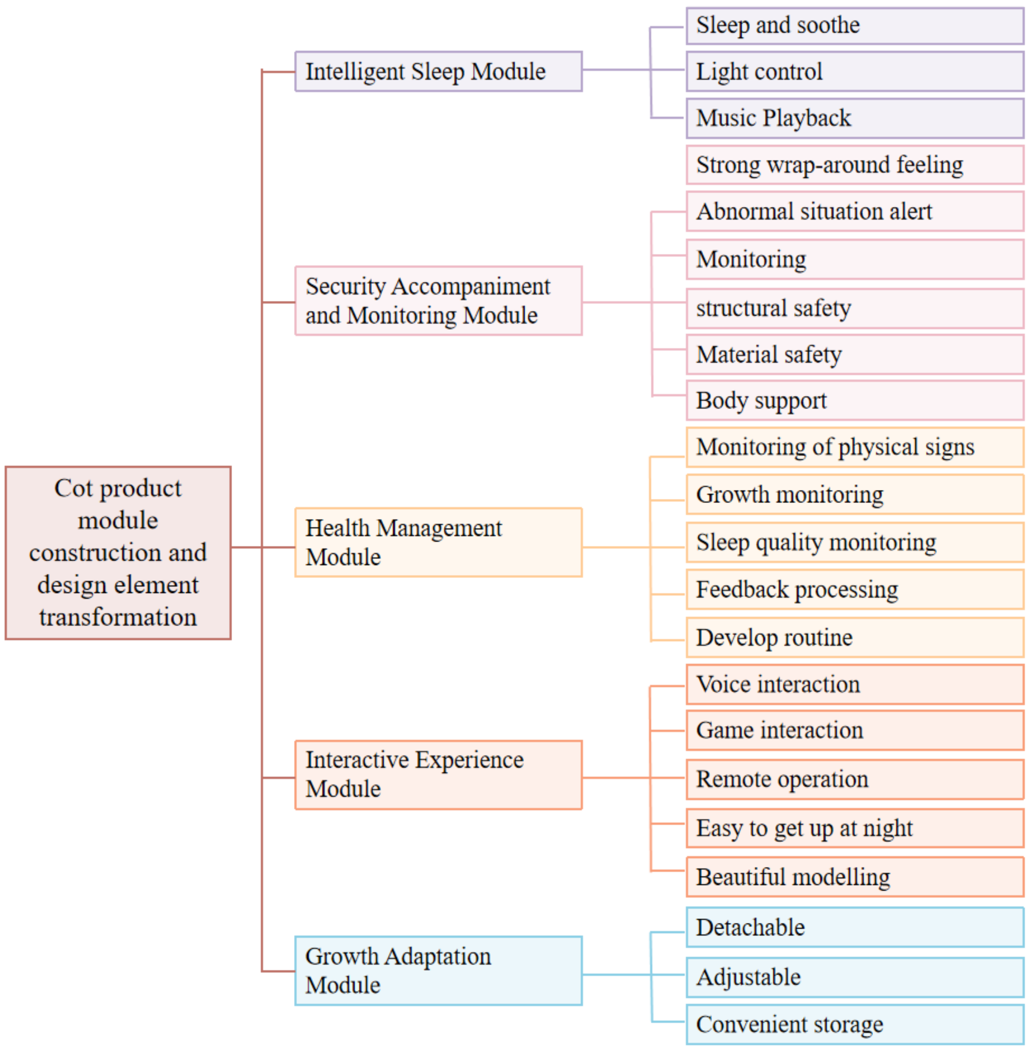

Fig. 10. Crib product module construction and design element transformation

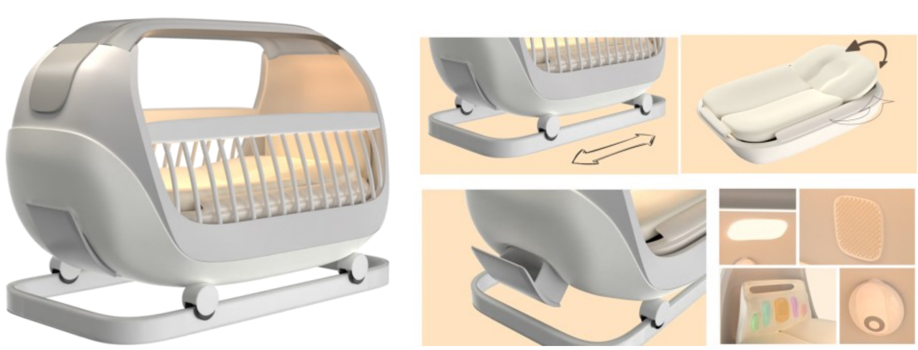

Fig. 11. Crib design solutions

This solution demonstrates the convenient feature of being able to join adult beds, thus facilitating the care of infants at night. The open design of both sides and the use of electrochromic glass at the top make the overall structure visually simpler and lighter, enhancing the interactivity of the crib. The overall shape of the crib adopts a womb-like fully-enclosed structure, giving the baby a full sense of security and wrapping, and at the same time creating a dim sleeping environment to improve sleep quality; the top is made of electrochromic glass, which can adjust the transparency according to the time change to create a suitable sleeping atmosphere for the baby. The crib is equipped with an intelligent monitoring system, including a high-definition camera and abnormal situation reminder function, which can monitor the baby's dynamics in real time and send reminders to parents in time. The mattress is equipped with intelligent adjusting function, which can automatically adjust the angle according to the baby's sleep state, preventing problems such as choking and head deviation. In addition, it is equipped with intelligent functions such as rocking and soothing, music playback, voice interaction, *etc*. These functions can help the baby fall asleep quickly. In terms of design details, the crib enclosure adopts a removable fence design, which is convenient for splicing with a queen-size bed and ensures the convenience of night care; the nappy storage space is integrated at the end of the bed for invisible storage to meet the usage habits of parents. The overall design not only focuses on the functionality of the product, but it also takes into account the aesthetics and humanisation, aiming to provide a safe, comfortable and intelligent sleeping environment for mothers and babies.

User experience evaluation of crib design solutions

The fuzzy comprehensive evaluation method utilizes fuzzy mathematics as its foundation, applying fuzzy relation synthesis principles to quantify ambiguously bounded factors and conduct multidimensional assessment of evaluated subjects. The operational procedure entails: establishing an evaluation index set; determining factor weights and corresponding membership vectors; constructing the fuzzy judgment matrix; and deriving comprehensive evaluation results through normalized fuzzy operations combining the matrix with factor weight vectors (Xu 2023).

Fig. 12. Plot representation of sample cases

According to the summarized characteristics of the new generation of mother and child lifestyles combined with the actual situation of the program, the following six indicators and indicator weights were set to evaluate the program: Set the evaluation indicator ensemble U = {intelligent, safe, convenient, functional, diversified, personalized}. Set the set of comments as E = {very satisfied, satisfied, average, dissatisfied, very dissatisfied}, and assign the value of each grade as E = {90, 75, 60, 50, 40}. First, the baby crib, which is currently the leading seller on the Tmall platform, was selected as a sample case and used as a reference for the final design. As shown in Fig. 12, the crib has outstanding performance in the market, and its practicality and value are widely recognized.

Through comparative evaluation and analysis, it can effectively test whether the designed solution can meet the actual needs of users. A total of 20 evaluators, including children's product designers, actual users of the crib, and infant growth experts, were invited to professionally evaluate the design solutions of the crib and the selected sample cases.

The weight of each factor was determined by conducting questionnaire research on the evaluation team, referring to the 1 to 9 importance judgement scale table for evaluation, and obtaining the weight coefficients of each indicator, as shown in Table 12, and passing the consistency test, as shown in Table 13.

Constructing a fuzzy comprehensive evaluation matrix: A comprehensive evaluation and analysis of the final design scheme and sample case were conducted by the evaluation team, and the data were normalized such that the sum of each row of the matrix is 1 (Wang *et al.* 2021), and a fuzzy comprehensive evaluation matrix R is obtained:

$$R_1 = \begin{bmatrix} 0 & 0.1 & 0.6 & 0.3 & 0 \\ 0.5 & 0.3 & 0.2 & 0 & 0 \\ 0.2 & 0.6 & 0.2 & 0 & 0 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0.1 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0.4 & 0.5 & 0.3 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 & 0 \\ 0.4 & 0.6 & 0 & 0 & 0 \\ 0.7 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.5 & 0.2 & 0. & 0 \\ 0.1 & 0.5 & 0.3 & 0.1 & 0 \end{bmatrix}$$

Fuzzy composite judgments, matrix synthesis operations, and normalization were performed to obtain fuzzy composite evaluation vectors for each of the 2:

M1=A×D= (0.339, 0.393, 0.235, 0.033, 0.000)

M2=A×D= (0.499, 0.368, 0.129, 0.004, 0.000)

Combined with the weighted calculation of the comment set scores, the overall score of the selected crib sample case was 75.73, and the overall score of the final design solution was 80.45. This resulted in the user satisfaction level of both crib designs being “satisfied”, and the final crib design solution was significantly better than the sample case. Thus, the crib design as a whole met the needs and preferences of users, especially in terms of intelligent operation, safety, functionality, and personalization of shape. This means that the crib design as a whole met the users’ needs and preferences, especially in terms of intelligent operation, safety, functionality and personalised shape. However, there were still deficiencies in some details, mainly in the design of convenience, such as flexible movement and nappy storage, which need to be improved in the later design.

Table 12. Each Indicator and Indicator Rights Recapture Table

	Intelligence	Safety	Convenience	Functional	Variety	Personality	Weight
Intelligence	1	1/7	1/5	1/3	1/2	3	6.57%
Safety	7	1	2	3	5	7	40.90%
Convenience	5	1/2	1	2	3	5	24.86%
Functional	3	1/3	1/2	1	2	3	14.58%
Variety	2	1/5	1/3	1/2	1	2	8.71%
Personality	1/3	1/7	1/5	1/3	1/2	1	4.38%

Table 13. Results of the Consistency Test

λ_{max}	CI	RI	CR	Consistency Test Results
6.179	0.036	1.260	0.028	Pass

CONCLUSIONS

1. This study integrates the semiotics approach of product architecture design (SAPAD) model with the Analytic Hierarchy Process (AHP) to identify user needs and design pain points for infant cribs within mother-infant populations. As a multi-user product, this methodology resolves the challenges of disorganized research data and ambiguous priorities inherent in multi-user studies, providing a scientific framework that delivers clear design guidelines and facilitates the clarification of design rationale.
2. This study adopted maternal-infant lifestyles as its research lens, conducting field research supplemented by literature analysis to examine maternal care behaviors. Through the SAPAD methodological framework, it established behavior–meaning–artifact mapping relationships. This approach thus established a transformative pathway from user insights to design priorities.
3. Building upon this foundation, design implementation and evaluation were conducted to scientifically develop solutions that provide detailed caregiving conditions. These addressed infant sleep challenges and alleviated the pressures of parenting. This co-design framework integrated users, experts, and designers, resolving ambiguous complexities inherent in crib design due to distinct user demographics. This further established a theoretical foundation and practical framework for future infant furniture research.

ACKNOWLEDGMENTS

Participants

This study involved human participants (children) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and relevant national guidelines for research involving human subjects. The research protocol was designed to ensure the protection of participants' rights, safety, and well-being. Written informed consent was obtained from the parents or legal guardians of all participants prior to their inclusion in the study.

Ethics Statement

The authors confirm that all methods were carried out in accordance with relevant guidelines and regulations. The study was performed in accordance with the 1964 declaration of HELSINKI and later amendments. The authors confirm that all experimental protocols were approved by the Ethics Committee of Nanjing Forestry University. The informed consent was obtained from all subjects and their legal guardians. The subjects are aware of the research background, process, results, and objectives, and sign a written informed consent form.

Data Accessibility Statement

All relevant data are within the paper.

Use of Generative AI

During the preparation of this work, the authors used ChatGPT in order to improve language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

REFERENCES CITED

Arnoldov, V. A. (1892). "A few observations on Dr. Auvard's baby bed warmer," *Journal of Obstetrics and Women's Diseases* 6(5), 516-517. https://doi.org/10.17816/JOWD65516-517

Baddock, S. A. P., Melissa, T. B., Peter, S. P., Anna, S. E., Dawn, E. G., and Barbara, C. (2019). "The influence of bed-sharing on infant physiology, breastfeeding and behaviour: A systematic review," *Sleep Medicine Reviews* 20, 19-43.

Ball, H.L., Taylor, C.E., and Yuill, C.M. (2021). "A box to put the baby in: UK Parent perceptions of two baby box programmes promoted for infant sleep," *Int. J. Environ. Res. Public Health* 18, 11473. https://doi.org/10.3390/ijerph182111473

Cao, C., and Deng, W. (2019). "Design of growth baby stroller based on computer aided innovation," *MATEC Web of Conferences*. https://doi.org/10.1051/matecconf/201926702005

Fei, W. R. (2022). *Research on Intelligent Furniture Design Methods Based on Older People's Lifestyle*, Master's Thesis, Dalian University of Technology, Dalian, China.

Ferrara, M., and Russo, A. C. (2018). "Next smart design: Inclusion, emotions, interaction in the concept of baby soothing, caring and monitoring smart solutions," *Springer, Cham*. https://doi.org/10.1007/978-3-319-73888-8_104

Jabbar, W. A., Shang, H. K., Hamid, S. N. I. S., Almohammedi, A. A., Ramli, R. M., and Ali, M. A. H. (2019). "IoT-BBMS: Internet of Things-based baby monitoring system for smart cradle," *IEEE Access* 7(1), 93891-93805. https://doi.org/10.1109/ACCESS.2019.2928481

Kaittan, A. S., Hameed, S. M., Ali, N. K., and Ali, M. H. (2020). "Smart management system for monitoring and control of infant baby bed," *International Journal of Electrical and Computer Engineering* 10, 5025-5031. https://doi.org/10.11591/ijece.v10i5.pp5025-5031

Kim, K., and Cha, K. (2021). "A study on the development of smart bassinet for infants using ICT," *Journal of Industrial Design Studies*. https://doi.org/10.37254/ids.2021.03.55.06.63

Lazer, W. (1963). "Life style concepts and marketing," *Toward Science Marketing*, 140-151.

Li, S., and Sun, B. (2018). "Research on smart baby stroller based on analysis of infant life style," *IEEE*, 1129-1134. DOI: 10.1109/HPCC/SmartCity/DSS.2018.00189

Liu, Y. Z., Guo, Y. Q., Song, Y. Z., Zou, L., and Ma, L. Y. (2022). "Infants' and children's sleeping styles and their impact on sleep quality," *Chinese Journal of Contemporary Paediatrics* 24(03), 297-302.

Lu, C. F., Zhu, Y. Q., Wu, J. F., Yao, J.. (2023). "Research on the design of same-city freight service based on SAPAD," *Packaging Engineering* 44(02), 180-187.

Pratap, N. L., Anuroop, K., Devi, P. N., Sandeep, A., and Nalajala, S. (2021). "IoT based smart cradle for baby monitoring system," *IEEE* 9358464. https://doi.org/10.1109/ICICT50816.2021.9358684

Wang, J., Siddicky, S. F., Carroll, J. L., Rabenhorst, B. M., Bumpass, D. B., Whitaker, B. N., and Mannen, E. M. (2021). "Infant inclined sleep product safety: A model for using biomechanics to explore safe infant product design," *Journal of Biomechanics* 128, 110706. https://doi.org/10.1016/j.jbiomech.2021.110706

Wang, S. Y. (2022). *Research on the Design of Mobility Aid Products for the Elderly from the Perspective of User Behaviour*, Master's Thesis, China University of Mining and Technology, Xuzhou, China.

Wang, Y. X. (2018). *Research on the Design of Family Intergenerational Caregiving Products Based on SAPAD*, Master's Thesis, Guangdong University of Technology, Guangzhou, China.

Wang, Y., Zhou, J. J., and Shi, Y. W. (2021). "Design of children's educational robot based on fuzzy hierarchical analysis approach," *Packaging Engineering*. https://doi.org/10.19554/j.cnki.1001-3563.2021.10.021

Xu, R. (2023). *Study of Children's Growable Study Tables and Chairs*, Master's Thesis, Nanjing Forestry University, Nanjing, China.

Yang, B. L., and He, R. K. (2023). "Research on interactive product design for e-learning based on SAPAD and scenario-based thinking," *Packaging Engineering*. https://doi.org/10.19554/j.cnki.1001-3563.2023.02.019

Yi, C. L., Xi, X. Y., Tong, M. L., Zhu, L., Zhang, H., Liu, Y. F., Huang, Y., Zhang, Y. H., Zhang, L. L., Cui, X. H., *et al.* (2023). "Demand analysis of infant and young child family nurturing care guidance," *Chinese Journal of Child Health* 31(01), 32-36.

Zhang, R. R. (2023). *Design of Intelligent Cooking Machine Based on the Lifestyle of Post-90s Young Families*, Master's Thesis, Nanchang University, Nanchang, China.

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