Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Creative Design Theory Research for Smart Product Service System

Xiaohong Mo
Guangdong University of Technology
Zhikai Lv
Guangdong University of Technology
Ding-Bang Luh
Guangdong University of Technology
Xian Yang
yangxian@gdut.edu.cn
Guangdong University of Technology

Article

Keywords: Smart PSS, Motivation logic design, Creative design, Motivation, Underlying needs

Posted Date: September 17th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7045991/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

With the advancement of sustainable development and intelligent technology, Smart Product Service Systems (Smart PSS) have gained popularity. However, their diversified forms, ecological attributes, and stakeholder coordination pose challenges for traditional designers. This paper categorizes traditional design into physical and behavior logic design based on the S-O-R model, and introduces motivation logic design focusing on the implicit motivations. By shifting emphasis from explicit needs and behaviors to implicit motivations, motivation logic design offers ample design space and depth, adapting to diversified forms, ecological considerations, and benefit-related developments. The smart sports bra example, analyzed using the think aloud protocol, demonstrates motivation logic design's advantages in quality and quantity of design innovations. It addresses Smart PSS design challenges and achieves Need beyond User Expectations (NBUE) solutions, emerging as a novel paradigm for complex product design and a theoretical framework for Smart PSS and collaborative design innovation.

1 Introduction

With the development of IT technologies, such as the Internet of Things (IoT) and Cyber-Physical Systems (CPS), Smart Connected Products (SCPs) are gradually entering the market. This integration of smart and service-oriented SCPs has sparked an emerging business model driven by human-centered technology, namely Smart Product Service Systems (Smart PSS) (Aleikish et al., 2025), Smart PSS products exhibit complex forms, involving not only tangible products but also intangible services (such as APP services accompanying the product). In addition, the ecologicalization of product stakeholders has become a trend in Smart PSS, encompassing collaborative innovative design of products and the pursuit of win-win benefits among multiple parties. Taking the smart sports bra product as an example, as a Smart PSS, its product form transcends the traditional bra concept, significantly diminishing the role of traditional fashion designers. The technological elements represented by IT 4.0 and IT 5.0 have become the highlights of the product (Monferdini et al., 2025; Suijkerbuijk et al., 2024). For instance, a paper recently published in Nature realizes a wearable electronic system with super strong moisture absorption and sweat-wicking capabilities, long-term monitoring of biological signals, and the ability to be integrated into the skin or textiles (Zhang et al., 2024). This necessitates the involvement of mechanical and electrical engineers who are familiar with various smart sensors, flexible materials, etc., in the design of smart sports bra products. The management of data collected by sensors and the mining of data value require the participation of computer research and development engineers and the health service industry. The medical beauty industry, seizing the opportunities presented by breast correction and breast care, has also actively participated. For product managers and product sellers, they utilize sensors and apps to collect user data on product usage, in order to continuously improve products, provide sustainable design and value-added services (Yang. et al., 2024), and obtain a continuous stream of value-added benefits. As for the end users of the product, they not only consider their own needs for the product but also worry about the constraints of social norms on wearing sexy bras.

Traditional designers are often constrained by existing technology, supply chains, production conditions, and the inherent form of the product when designing human factors, appearance, materials, and other aspects of the product (Luchini et al., 2023). The depth of design exploration they can achieve is limited. When faced with challenges such as diversified product forms, ecological demands, and extensive stakeholder involvement, traditional product designers often feel powerless and struggle to cope with this situation (Orwig et al., 2024). To address this problem, it is necessary to expand the design and innovation space for designers, elevate the starting point of product design, and ensure that this starting point is independent of the inherent forms of industries, technologies, products and services. This will provide product designers with sufficient space for innovative design. Additionally, it facilitates collaborative participation by product stakeholders, particularly technology engineers, to adapt to the various challenges faced by current Smart PSS designs. However, there is currently no suitable creative design theory available. The effectiveness of human technologies such as ICT and CPS hinges on a reasonable creative design theory and a framework for multi-party collaboration, which enables ICT and CPS to provide data acquisition and other technical support for the design framework (Lou, 2023; Song, 2025).

This paper, based on the interdisciplinary characteristics of Smart PSS, provides a review of the research framework of design paradigms and related supporting theories. It explores design methods and related theories that offer deeper design starting points and broader design spaces, aiming to guide the design of complex product forms and address the challenges posed by product form diversification, ecological demands, and extensive stakeholder participation in complex system designs such as Smart PSS.

2 Literature review and research hypotheses

2.1 Research context of motivation logic design paradigm

Modern design originated at the Bauhaus School in 1919, and functionalism emerged as the dominant trend in product design during that period (Eisele, 2008). At this stage, design focused on the intrinsic properties of the object (or product), including appearance, structure, materials, and practical functions, primarily within the context of physical entities such as products, buildings, and industrial designs. The primary objective was to enhance the product's attractiveness, functionality, and durability. Product design also encompasses the environment in which product users are situated, a concept often referred to as user scenario design in design studies. This paper terms the design paradigm at this stage as the physical logic design paradigm. Physical logic design refers to a design approach guided by the logical attributes of products and services, including design logic (e.g., information architecture, navigation design), rationality (e.g., user selection before operation), and integrity (e.g., adherence to system rules).

During World War II, ergonomics began to develop in order to improve the efficiency of task execution and reduce personnel errors in the human-machine interfaces of military equipment such as airplanes (Fitts, 1992). In 1960, Licklider published a paper titled "Man-Computer Symbiosis," which first proposed the concept of human-computer interaction. This paper is regarded as a significant milestone in the field of human-computer interaction (Licklider, 1960). Although concepts such as ergonomics, human-computer interface, and human-computer interaction all account for human factors, research on human-computer interaction at this stage primarily focused on technology. As human technology matured, people gradually began to emphasize "user-centered" human-computer interaction. Gradually, various user-centered concepts emerged, including usability engineering, interaction design, behavior logic design, and user experience design. Among these concepts, interaction design has significantly evolved from human-computer interaction and has had a profound impact. In his book "Designing Interactions," Mogridge extensively explores the principles and practices of interaction design, and it can be said that he proposed and promoted the development of this field (Moggridge & Atkinson, 2007). Norman is considered one of the key figures in the field of interaction design. His book "The Design of Everyday Things" delves into the principles and concepts of design and user interaction, which has had a profound influence on the development of interaction design (Li et al., 2025; Norman, 2004; Tenner, 2015). "User-centered" design emphasizes that products, services, or systems must meet the needs, expectations, and behavioral patterns of users. Extensive research has been conducted on user behavior patterns, particularly in this regard. Based on the viewpoints of this period, these designs can be categorized as behavioral logic. Therefore, this paper refers to this stage of design as the behavior logic design paradigm. Behavior logic design refers to a design approach guided by user behavior and its goals, emphasizing the smoothness of task completion (e.g., no cognitive friction), convenience (minimizing the operational behavior flow), and user experience (making the operational process enjoyable).

With the development of cognitive psychology and cognitive neuroscience in the last century, research on individual motivation and cognition has become increasingly in-depth. This research has been supported by advanced devices such as eye trackers, polysomnography, electroencephalography, and magnetic resonance imaging. These technological advancements have made it possible for explicit behavioral research to shift towards implicit cognitive research (Liao, 2025; Naiseh et al., 2023). In fact, several studies have already explored cognitive or motivational design. For instance, the Fogg Behavior Model suggests that behavior cannot occur without motivation, ability, and triggers (Fogg, 2025). Additionally, persuasive design utilizes psychological theories and methods to change users' behavior and attitudes

through appropriate persuasive strategies and intentions, thereby influencing and guiding users through design (Whalen, 2011; Youn & Baek, 2024). However, despite these efforts, design studies have failed to distinguish between behavioral logic and motivational logic, leading to conceptual ambiguity and a lack of a comprehensive theoretical system addressing motivation. Therefore, building upon physical logic design and behavior logic design, this paper introduces the concept of motivation logic design and refers to design based on cognitive mechanisms such as motivation as the motivation logic design paradigm.

Motivation logic design and behavior logic design are both user-centered designs, but their starting points shift from explicit needs and behaviors to implicit motivations. Since motivation logic design starts earlier, designers can identify more conflicting elements during the problem-construction phase. This leads to a deeper level of design exploration and ultimately results in more innovative and high-quality design solutions. Reiter-Palmon et al. (2023) argue that the greater the conflict between the elements retained in problem-solving, the more novel and high-quality the solution will be (Fiorineschi et al., 2022). Furthermore, implicit motivation is unrelated to specific industries, technologies, products and services, meaning that motivation logic design has a broader design space and can generate a larger number of design solutions (Koutstaal et al., 2024). Design space and design exploration level are two key indicators for measuring a design method and theory (Shah et al., 2003; Tan & Luhrs, 2024; Zhang et al., 2025). To support these viewpoints, this paper proposes the following hypotheses and evaluates the quality of design innovation through Divergency Index (DI), and the quantity of innovative design ideas through the Micro Ideation Index (MII).

H1(a): Compared to traditional design paradigms, motivation logic design can produce design innovation solutions of better quality.

H1(b): Compared to traditional design paradigms, motivation logic design can produce a greater number of innovative design solutions.

2.2 Research context of internal mechanisms of motivation

Motivation research spans multiple disciplines, and the explanations of motivation within each discipline are not fully consistent, resulting in a diverse and heterogeneous body of motivation research. However, despite these differences, motivation studies share a common focus on the variables and processes that determine the initiation, direction, and maintenance of behavior (Wright et al., 2013). This focus aligns with the S-O-R model of motivation. The S-O-R model proposes that external factors can influence an individual's motivation, as well as other cognitive and emotional processes, ultimately shaping their decisions and behaviors (Mehrabian & Russell, 1974). Numerous studies have utilized the S-O-R model to demonstrate significant relationships among cognition, emotion, motivation, preferences, and methodologies (Orth & Wirtz, 2014). These studies highlight the crucial role that different cognitions, emotions, and motivations play in generating self-motivation and shaping preferences for decision-making and behavior (Damasio, 2001). To date, the S-O-R model has been extensively applied in the study of consumer behavior and motivation (Cortinas et al., 2019; Pilatin & Dilek, 2024; Yang et al., 2024). Huddleston et al. (2018) have advocated for the use of the S-O-R framework to investigate the behavioral responses and internal mechanisms of consumer motivation within various stimulus environments.

In studying the internal mechanisms of motivation, Ajzen proposed the Theory of Planned Behavior (TPB) in the fields of management psychology and cognitive economics, conducting in-depth research on how motivation alters an individual's behavior patterns (Ajzen, 1985, 1991, 2012). He believed that an individual's behavioral outcomes hinge on their motivation and abilities, with motivation comprising behavioral intention and its antecedents. TPB has achieved success both theoretically and practically, receiving numerous citations across various fields (Nayak et al., 2024; Schmidt et al., 2022), becoming an important research direction in management psychology and cognitive economics. Perugini and Bagozzi proposed the MGB (Model of Goal-Directed Behavior) based on TPB, which considers desire as the proximate cause of behavioral intention, with the traditional antecedents of TPB acting through desire. Compared to TPB, MGB

explains more variability in behavioral intention (Lee et al., 2024; Perugini & Bagozzi, 2004). More importantly, desire factors can better elucidate the direct causes of behavior and decision-making (Sharma et al., 2024; Taylor et al., 2005; Yildiz Durak, 2025). Desire stands as the core component of motivation. While desire and need share a high degree of similarity, desire belongs to a cognitive category, whereas need falls into an explicit behavioral category. Implicit desires and motivations determine explicit needs and behaviors, a finding confirmed by motivational psychology research (Lin & Chen, 2025; Wright et al., 2013). Based on this, this paper proposes further research topics: calculating implicit motivations/desires through explicit needs and behaviors, thereby achieving a design paradigm grounded in motivation logic.

H2: Through calculation, explicit needs can be transformed into implicit desires/motivations, thereby achieving a motivation logic design.

In research on the internal mechanisms of motivation in disciplines such as psychology, education, and management, the focus is primarily on how to adjust individual motivation to influence their corresponding behaviors and decisions. Examples include motivating individuals to reduce their car travel habits to decrease exhaust pollution (Bamberg et al., 2021), encouraging students' initiative to improve their foreign language learning (Mai, 2022), and the impact of an increased consumer moral identity on desires and decisions to purchase smart drugs (Sharma et al., 2024). However, in design studies, behavior and decision-making are not facilitated through adjusting individual motivations, but rather through designing product and service attributes that exceed user expectations, thereby activating user motivation and achieving user goals. Thus, it is necessary to determine how to calculate the corresponding implicit desires/motivations from explicit needs to achieve motivation logic design.

3 Practice and evaluation of motivation logic design

3.1 Conversion method between explicit needs and implicit motivation

3.1.1 Boundary between needs and motivation

Since explicit needs and behaviors are determined by implicit motivations, this paper infers implicit motivations based on explicit needs and behaviors. Through market research, user feedback, and user studies, product-related needs can be obtained, which are explicit and expected by users, corresponding to their expected solutions. Explicit needs may not necessarily reflect real motivation. For instance, users may express a need to purchase sexy bras, which is an explicit need, but their true motivation may be to showcase their body shape, gain envy or attention, or desire higher self-expression. This is an implicit motivation that belongs to the cognitive category and is unrelated to industries, technologies, products, and services. It is formed before the specific product design scheme is developed. To motivate these motivations, it doesn't necessarily have to be through sexy bras; other means such as a tight-fitting outfit, a certain sport, or a live streaming event could also suffice. Designers can only create more innovative and achieve solutions beyond user expectations by understanding these deep-seated and implicit motivations.

In order to further distinguish the relationship between explicit needs and implicit motivations, this paper introduces Maslow's Eight-Level Theory of Motivation (METM) (Brady, 2007; Neher, 1991), providing a clear direction and analytical path for the process of motivation transformation. METM divides human primal motivations into eight stages, as shown in R1 of Table 1. Based on these eight stages of motivation, this paper constructs their corresponding secondary motivation indicators, as shown in R2 of Table 1, where R1 $\supseteq$ R2. R3 represents the explicit needs for a certain product or service. Currently, there is a lack of research on the relationship between implicit motivations and explicit need transformation, and there are no specific methods and processes for transforming this relationship. If the transformation

from R3 to R2 in Table 1 can be achieved, the paradigm shift from behavior logic design to motivation logic design can be realized.

Table 1
METM and its secondary and tertiary indicators

R1: METM/ Original motivation	R2: Motivation/Desire (Common factors)	R3: Explicit needs (Needs of smart sports bra)
Physiological needs	Food, water, air, sexual needs, etc	-
Security needs	Stable, safe and healthy, protected, orderly, able to relieve fear and anxiety, etc	V16 chest health check; V17 real-time physical sign monitoring; V18 abnormal physical signs warning; V19 automatically adjusts and fits the chest; V22 modular and detachable; V24 motion consumption/target prompt; V25 scientific motion planning; V30 reduces sports odor
Love and belonging	Connections or relationships with others, exercise and social	V26 sports-based recommendation for making friends; V27 sports competition prompt (such as step ranking version); V28 assisted APP allows one click sharing of exercise status; V29 Wear Smart Sports Bra for Exercise
Esteem needs	Respect for oneself and others	-
Cognitive needs	Knowledge and understanding, curiosity, exploration, meaning, and predictability needs	-
Aesthetic needs	Appreciate, seek beauty, aesthetic appearance, etc	V13 bra exterior design; V14 modified breast shape/modified accessory breast;
Self actualization	Realize oneself, improve oneself, take care of and perfect oneself	V21 chest correction; V23 correction of exercise posture; V15 Heating/massage of bras to relieve pain; V20 Heating/massage of bras for breast enhancement
Transcendence needs	Beyond personal values-	-

Table 1 provides a precise description of METM/original motivation, motivation/desire, and explicit needs, which is helpful for clarifying their relationships. Literature indicates that desire, a secondary indicator of motivation, is closely related to a person's primal motivation (Beckmann & Heckhausen, 2018; Deci & Ryan, 2000). Positioned between R1 and R2, this explanation suggests that desire is unrelated to industries, technologies, products and services. However, there are also studies explaining that desire is a specific manifestation of primal motivation (Berridge & Kringelbach, 2015; Deci & Ryan, 1985). When motivation leads individuals to have a strong desire for a specific outcome or experience, this desire transforms and provides clear direction and goals for the original motivation, indicating how individuals should act to satisfy these internal driving forces. This perspective aligns more closely with R2 and R3 mentioned in Table 1. The unclear boundary explanation may be due to the lack of specific applications, and METM has not fully clarified the relationship between needs and motivations. To address this research gap, this paper proposes a precise description as shown in Table 1, which clearly delineates the boundaries related to motivation. By adding a secondary motivation indicator between original motivation and explicit needs, the article distinctly differentiates between motivation logic design and behavior logic design in the design basis.

3.1.2 Conversion from needs to motivation

Since a person's explicit needs are driven by their motivation, the explicit needs of a product or service can be converted into a secondary motivation indicator (R2) through a specific method or calculation, aligning with the original motivation

framework of METM. This paper employs factor analysis to achieve this objective, as it enables the calculation of the underlying patterns among various factors. The naming of these common factors (R2) can serve as a reference to the eight stages of original motivation (R1) outlined in METM.

Taking sports bras as an example, a questionnaire outline was designed based on the collected needs, consisting of a total of 34 items numbered v0 to v33. Among them, items v0 to v11 are categorical variables related to user characteristic information, such as age, education level, and other relevant details. Items v12 to v33, on the other hand, are quantitative variables that measure users' attitudes towards product need. In this survey, 282 valid questionnaires were distributed and collected, all from female users. Notably, the sample size for individuals aged 18–24 accounted for 80.7%, ensuring a sufficient sample size for the expected target user group. Reliability and validity analyses were conducted on the questionnaire, revealing a reliability coefficient of 0.856, which exceeds the threshold of 0.8, indicating high reliability quality of the research data. Regarding the "alpha coefficient with deleted items," no significant increase in the reliability coefficient was observed after deleting any item, suggesting that none of the items should be removed. In terms of questionnaire validity, the KMO value was 0.873, and the data successfully passed the Bartlett sphericity test ($p < 0.05$). These findings suggest that the questionnaire survey and its data possess good reliability and validity, making them suitable for factor analysis. When considering four common factors, their eigenvalues all exceeded 1. The variances explained by the rotated factors were 20.116%, 14.273%, 10.148%, and 8.803%, respectively. The cumulative variance explained by rotation amounted to 53.34%, which, although not exceptionally high, met the basic requirements for factor analysis.

In factor analysis, the maximum variance rotation method was employed to establish the correspondence between the common factor (R2) and the research items (R3). The commonality values for all research items exceeded 0.4, suggesting a robust correlation between the research items and the common factor, enabling the factor to effectively extract pertinent information. Based on the original motivation outlined in METM (Table 1), the common factors were named in accordance with the factor variables, yielding the data presented in Table 2. Consequently, through factor analysis, this paper has successfully transformed explicit needs into implicit motivations. Furthermore, H2 has been confirmed to be able to convert explicit needs into implicit desires/motivations through computation, achieving motivation logic design.

Table 2
Naming of common factors

Common factor (R2: Motivation)	No.	Factor variable (R3: Explicit needs)	Factor loading	Commonality	Explain the amount of variation	Accumulated explanatory variance
Safe and healthy	V16	Chest Health Check	0.578	0.505	20.116%	20.116%
	V17	Real time monitoring of physical signs	0.743	0.562		
	V18	Abnormal physical signs warning	0.462	0.455		
	V19	Automatically adjust and fit the chest	0.669	0.483		
	V22	Modular and detachable	0.604	0.444		
	V24	Sports consumption/goal prompts	0.525	0.408		
	V25	Scientific Movement Planning	0.628	0.467		
	V30	Reduce sports odor	0.644	0.461		
Exercise and Social	V26	Sports based recommendations for making friends	0.828	0.711	14.273%	34.389%
	V27	Sports competition tips	0.62	0.535		
	V28	Assist APP for sharing of exercise status	0.826	0.69		
	V29	Wear smart sports bras for exercise	0.651	0.484		
Care and improvement	V21	Chest shape correction	0.435	0.444	10.148%	44.538%
	V23	Correcting exercise posture	0.625	0.532		
	V15	Heating/massage of bras to relieve pain	0.58	0.504		
	V20	Heating/massage of bras for breast enhancement	0.55	0.538		
Aesthetic appearance	V13	Bra appearance design	0.634	0.662	8.803%	53.340%
	V14	Modifying chest shape/modifying accessory breasts	0.8	0.694		

3.2 Protocol analysis experiment for motivation logic design

Design itself is inherently subjective and inevitably influenced by the designer's personal experience (Koutstaal, 2024). To verify whether motivation logic design offers significant advantages in terms of both the quality and quantity of design innovation, compared to physical logic design and behavior logic design, and to further demonstrate that motivation logic design possesses a broader design space and deeper exploration capabilities, thereby better adapting to the challenges posed by Smart PSS, this paper employs the think aloud protocol analysis experiment to quantitatively assess the quality

and quantity of design innovation in motivation logic design. In this manner, it aims to prove that superior design results are attributable to advanced design methods, rather than being influenced by the designer's own experience.

3.4.1 Experimental environment and designer participants

This experiment was conducted in a design studio. To avoid mutual interference during the experiment, each participant made an appointment for the experiment time, and only one participant was invited for each experiment time. The experimental environment, including light, sound, and other variables related to the experiment, is kept consistent. When participants are invited to the studio, they will be introduced to specific experimental tasks and related task requirements through pre recorded voice. There are two experimenters in this experiment, one of whom is a doctoral student with 11 years of design experience; One is a graduate student with 5 years of design experience.

A total of 70 participants were recruited for the experiment, all of whom were selected as the target user group through a questionnaire survey. They are all designers with more than 4 years of design experience. Using an inter subject experiment, all participants were evenly divided into experimental group and control group based on their profession, design experience, and gender, ensuring consistency in all variables except for differences in design methods used by different experimental groups. Through pre recorded audio introductions, all participants were informed of the basic knowledge of the entire design process and were informed of the basic procedures of the experiment, as well as signing informed consent forms. The total duration of the experiment is about 30 minutes, and after the experiment, each participant was paid 30 RMB.

3.4.2 Experiment design

Task of the experimental group: (1) Preparation of materials before the experiment: Please listen to the voice introduction and understand its design logic. It is crucial to grasp the design logic in order to officially start the experiment. Once you are confident in your understanding, you may proceed. If you have any uncertainties, please inquire with the experimenter, who will address all your questions. (2) Formal experiment begins: Take "Exercise and Chest Care" as the design object and utilize the following factors as design points: "Exercise and Social", "Safety and Health", "Care and Improvement" and "Appearance Aesthetics". Develop three plans that you consider to be superior. (3) Experiment duration: 20 minutes. (4) Number of design proposals: 3.

Task of the control group: (1) Preparation of materials before the experiment: Listen to the voice introduction. Your task is to devise the best product design plan. Once you are confident in your understanding, you may proceed. If you have any uncertainties, please inquire with the experimenter, who will address all your questions. (2) Formal experiment begins: Based on the topic and needs for the "sports bra", utilize your design knowledge and methods to select the most appropriate design approach or approaches. Develop three plans that you consider to be superior. (3) Experiment duration: 20 minutes. (4) Number of design proposals: 3.

Throughout the entire experiment, both groups were required to express their thoughts, feelings, and ideas during the design process. The experimenter could prompt participants to articulate their thoughts verbally and ensure the smooth progression of the experiment. This experiment utilized a digital camera for video recording, with the audio being transcribed into text, segmented, and encoded for subsequent data analysis.

3.3 Quality and quantity evaluation of design innovation

3.3.1 Design ideas and examples

The ideation of the design process, also referred to as “micro ideation”, is characterized as “exploring design possibilities” and “generating ideas”. Considering atomic cognitive processes and structures, scholars argue that design ideations emerge during the design process and require attention to both process- and outcome-based indicators (Hernandez et al.,

2010; Shah et al., 2003; Wu et al., 2025). As an effective user research method, the think aloud approach facilitates obtaining genuine feedback and ideas from participants throughout the experimental design process. In this experiment, the think aloud method is applied to gain deeper insights into participants' conceptual design processes, uncovering their underlying thinking logic and creative generation mechanisms. This method has the capability to capture participants' real-time thinking trajectories during the design process, thereby aiding in a more comprehensive understanding of their creative processes, conceptual evolution, and problem-solving strategies.

For instance, the experimenter documented three solution examples for a participant in the experimental group, as illustrated below: (1) Nanotechnology and intelligent temperature-regulating bra: Utilizing nanotechnology, intelligent temperature-regulating materials are crafted to automatically adjust the bra's internal temperature according to ambient conditions, providing a comfortable wearing environment. (2) Biotechnology and intelligent growth bra: By integrating biotechnology with intelligent fibers, an intelligent growth bra is designed to adapt to changes in the wearer's body size, automatically adjusting its size as the wearer grows. (3) 3D printing technology and personalized bra customization: Leveraging 3D printing technology, bras that are both snug-fitting and comfortable, with unique designs, can be customized based on the wearer's body data and personalized preferences.

The experimenter documented three solution examples provided by a participant in the control group, as outlined below: (1) Bra Matching: Suitable for sports scenarios, these bras can be well-matched with the wearer's skin color, body shape, temperament, and other factors, encompassing appropriate bra styles and colors. (2) Wearable Technology and Intelligent Health Monitoring Bra: Incorporating wearable technology and intelligent sensors, an intelligent health monitoring bra is designed to monitor the wearer's health status in real-time, aiding in the timely prevention and detection of health issues. (3) Sweat-Absorbent Material Sports Bra: Utilizing the latest materials, this bra effectively absorbs sweat generated during exercise while maintaining good breathability, preventing sweat accumulation, odor, and potential harm to the body.

3.3.2 Design ideation encoding

The recorded voices of participants are converted into text, which is then segmented into short phrases to simplify and encode the ideas expressed during the experimental design process. For example, "outerwear style" (I believe another significant aspect of bras is their decorative use; bras don't necessarily need to be worn inside, they can also be worn as outerwear) and "back support function" (if it's for strength training, bras should incorporate a back support feature). Encoding these ideas allows for the evaluation of their innovativeness and quantity within the design ideations.

This paper employs two coding schemes: the ideation coding scheme and the cognitive coding scheme with five cognitive levels. Among them, the ideation coding scheme is primarily used to measure the MII, while the cognitive coding scheme is mainly used to measure the DI.

Regarding the cognitive coding scheme, since the design ideation involves cognitive processing by the participants, this paper adopts a coding scheme comprising five cognitive levels: Representation (R), Perception (P), Function (F), Evaluation (E), and Goal setting (G). By encoding the think aloud during design activities, the designers' thinking patterns are revealed through these five cognitive levels: R, P, F, E, and G. This hierarchical cognitive encoding method provides researchers with a framework for analyzing design ideations, enabling a more nuanced understanding of the structure and dynamics of cognitive activities during the design process.

In terms of the ideation coding scheme, this paper proposes a scheme based on Lee and Ostwald's definition of identity, attributes, and behavior in micro-ideation (Lee & Ostwald, 2022; Wu & Acharya, 2024). The ideation coding scheme specifically focuses on the object description in product design, encompassing the three states of concept generation in the product design process: subject, functionality, and interaction. Among these, the first state, "subject", pertains to specificity, which involves the ability to distinguish one thing from another. It encompasses the conceptualized object or thing along with its specific components (such as "smart color-changing sports bra", "front zipper", "U-shaped shoulder

strap"), subject attributes (such as "nano material", "low saturation color", "minimalist style"), and subject features (such as "beauty", "practicality", "simplicity"). The second state, "functionality", defines the associated subject's functionality (such as "intelligent recording", "adaptive regulation") or technology (such as "AR technology", "microelectronics technology"), as well as the considered object (such as "health data", "sleep time") or purpose (such as "pain relief", "body shaping"). Finally, "interaction" describes the ways in which the subject interacts (such as scaling, expanding) and its usage scenarios (gym scenes, running scenes). Overall, all design ideas expressed orally by participants can be encoded and statistically analyzed using at least one of the aforementioned subcategories. Through this approach, we can identify ideas, quantities, and diversity from each protocol.

4 Results

4.1 MII measurement based on ideation coding scheme

The MII is an indicator that measures the frequency of creative ideas generated per unit time during the design process. It is primarily used to quantify the number of innovative design ideas produced within that process. This is accomplished by encoding and analyzing the verbal expressions recorded during the design experiment, with a focus on the order of magnitude of creative ideas, rather than their quality or originality. This paper calculates the average frequency of creative coding results per minute for participants using the ideation coding scheme, as illustrated in Eq. (1):

$$I = \frac{\sum F(a)*1}{T} \qquad (1)$$

Among them, F(a) represents the number of times a certain activity appears, specifically, the number of times a specific creative type emerges in the design process. ∑F(a) signifies the aggregate number of occurrences for all activities. T denotes the total duration of the design session devoted to standardized creative output. The reason for multiplying by 1 is that the total time of the design process is measured in minutes, and I represents the average frequency of creative encoding per minute. Through this formula, we can measure the frequency of creative ideas appearing in the design process to evaluate the designer's creative output at a micro level.

As shown in Table 3, the summary data for the MII of the experimental group is presented. Taking participant A01 in the table as an example, the design duration is 9 minutes and 47 seconds. During this time period, the total frequency of the subject creative encoding is 23, indicating that the subject creative encoding appears 23 times. The total frequency of functionality creative encoding is 14, meaning that functionality creative encoding appears 14 times. The total frequency of interaction creative encoding is 1, signifying that interaction creative encoding occurs once. Based on the provided data, the values of F(a) are as follows: F(Subject) = 23, F(Functionality) = 14, F(Interaction) = 1. The total duration of the design session, T, is 9.783 minutes. Using Eq. (1), we can obtain I = 3.884, which represents the result of the MII. This indicates that in a design session of 9 minutes and 47 seconds, 3.884 creative codes are generated per minute, evaluating the number of innovative design ideas. Similarly, a list of MII for the control group can be derived.

Table 3
Micro ideation index of experimental group

No.	Duration	Subject			Total	Functionality				Total	Interaction		Total	Summary	I
		Sp	Sa	Sf		Ff	Ft	Fo	Fg		Iw	Ipl			
A01	9:47	5	11	7	23	5	3	3	3	14	1	0	1	38	3.884
A02	14:03	0	3	5	8	4	0	2	2	8	0	0	0	16	1.139
A03	8:03	0	0	1	1	6	0	5	5	16	1	0	1	18	2.236
A04	12:06	0	4	2	6	7	1	2	9	19	0	2	2	27	2.231
A05	18:12	6	4	8	18	15	2	2	4	23	3	0	3	44	2.418
A06	13:29	3	9	10	22	16	0	3	3	22	1	1	2	46	3.412
A07	14:56	6	2	5	13	16	0	2	0	18	0	0	0	31	2.076
A08	15:27	6	1	5	12	15	1	1	3	20	1	0	1	33	2.136
A09	15:56	0	1	3	4	8	0	0	2	10	0	0	0	14	0.879
A10	19:05	3	10	7	20	10	1	1	6	18	0	0	0	38	1.991
A11	16:22	7	6	1	14	22	0	1	2	25	0	0	0	39	2.383
A12	15:50	7	3	0	10	19	0	4	5	28	0	0	0	38	2.4
A13	17:23	1	8	0	9	14	1	0	0	15	0	1	1	25	1.438
A14	9:10	3	11	6	20	7	0	0	0	7	0	0	0	27	2.945
A15	16:05	4	13	0	17	9	0	3	0	12	0	1	1	30	1.865
A16	10:12	3	7	7	17	8	0	1	0	9	0	0	0	26	2.549
A17	13:02	5	7	3	15	11	0	1	0	12	0	0	0	27	2.072
A18	10:54	2	3	2	7	12	2	1	2	17	0	0	0	24	2.202
A19	16:03	5	8	7	20	10	0	0	0	10	0	2	2	32	1.994
A20	20:45	7	4	7	18	8	6	4	7	25	1	2	3	46	2.217
A21	17:26	3	4	7	14	9	5	1	4	19	1	0	1	34	1.95
A22	16:20	5	2	3	10	14	4	4	4	26	2	5	7	43	2.633
A23	19:26	2	4	1	7	5	3	0	4	12	1	0	1	39	2.007
A24	14:00	4	3	4	11	11	4	2	4	21	0	4	4	20	1.429
A25	16:11	2	5	6	13	8	2	1	1	12	1	2	3	36	2.225
A26	12:28	3	2	1	6	4	2	2	2	10	2	2	4	28	2.246
A27	9:44	3	2	1	6	4	2	2	2	10	2	2	4	20	2.055
A28	12:08	4	5	3	12	4	1	2	3	10	3	2	5	27	2.225
A29	18:04	14	1	2	17	11	0	5	3	19	0	5	5	41	2.269
A30	15:22	4	5	5	14	13	5	4	3	25	1	1	2	41	2.668
A31	15:27	7	1	4	12	9	5	4	3	21	1	2	3	36	2.33

No.	Duration	Subject			Total	Functionality				Total	Interaction		Total	Summary	I
		Sp	Sa	Sf		Ff	Ft	Fo	Fg		Iw	Ipl			
A32	16:06	7	5	7	19	9	0	1	2	12	2	4	6	37	2.298
A33	12:12	3	3	7	13	2	2	2	2	8	4	1	5	26	2.131
A34	16:07	3	7	6	16	9	7	4	4	24	0	0	0	40	2.482
A35	18:15	1	9	8	18	7	4	0	3	14	0	6	6	38	2.082

Analyze whether there is a significant difference in the MII between the experimental group and the control group. Since the data did not follow a normal distribution, non-parametric tests were used to investigate the differences in MII between the experimental and control groups. The results showed that the experimental group and the control group exhibited significant differences in MII ($p < 0.01$). When comparing the median values, it is evident that the median value of the experimental group (2.225) was significantly higher than that of the control group (1.864). This finding indicates that the experimental group generated a higher frequency of creative ideas per unit time compared to the control group, and the difference is statistically significant.

4.2 DI measurement based on cognitive coding scheme

The DI is derived from the concept of information entropy and aims to quantify diversity and innovation in the design process, reflecting the cognitive allocation of participants at various cognitive stages. It serves as an effective tool for evaluating not only diversity and innovation in the design process, but also how designers explore and generate new design ideas through differing cognitive activities. Wide and diverse cognitive activities are often regarded as one of the key factors in fostering high-quality and original creativity. Consequently, the DI can be viewed as an indicator for assessing the quality and originality of creativity (Lee & Ostwald, 2022), as demonstrated in Eq. (2),

$$D = 2^{H} \qquad (2)$$

Among them, H represents information entropy, which is utilized to measure the uncertainty or complexity of information. A higher value of information entropy indicates that the designer's exploration of cognitive states or design activities is more extensive and diverse. The calculation formula for information entropy is:

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i \qquad (3)$$

Among them, Σ represents the total logarithm of the probabilities of all cognitive states, where p_i represents the probability of the i-th cognitive state or design activity occurring, and n represents the total number of cognitive activities performed by the participant within a certain period of time.

This paper calculates the DI using a cognitive coding scheme, in which designers can encode each stage of the design process into one of five levels: R, P, F, E, or G. When designers involve more diverse cognitive activities in the design process and the probability distribution of each activity is more balanced, the information entropy will be higher. As entropy serves as an indicator that measures the average information content of a probability distribution, the entropy value reaches its peak when the probabilities of all cognitive activities are similar, signifying a high degree of diversity and uncertainty. The DI is a function of information entropy; therefore, when the information entropy is high, the DI will also be high, reflecting a high diversity in the designer's design thinking.

The DI for the experimental group is presented in Table 4. Taking participant A01 in Table 4 as an example, the probability of R occurring is 0.083, with a frequency of 1; the probability of P occurring is 0.333, with a frequency of 4; the probability of F occurring is 0.167, with a frequency of 2; the probability of E occurring is 0.167, with a frequency of 2; and the probability of G occurring is 0.250, with a frequency of 3. Using the information entropy formula, as shown in Eq. (3), we substitute the probability p_i of each activity into the formula to calculate the information entropy H, which is 2.189. Subsequently, we use the information entropy H to compute the DI, resulting in $D \approx 4.559$. By applying the same method, we can obtain a list of the DI for the control group.

Table 4
Divergency index of experimental group

No.	Encoding result	Probability of event occurrence					H	D
		R	P	F	E	G		
A01	PGPRFPGPEGEF	0.083	0.333	0.167	0.167	0.250	2.189	4.559
A02	PRGRPRFEPRFPRE	0.357	0.286	0.143	0.143	0.071	2.121	4.350
A03	PGEFPGRGPE	0.100	0.300	0.100	0.200	0.300	2.171	4.503
A04	PGPRERPFRPGRFR	0.357	0.286	0.143	0.071	0.143	2.121	4.350
A05	PFGRPRPFRFPEFPE	0.200	0.333	0.267	0.133	0.067	2.149	4.436
A06	PGRPRFERFPR	0.364	0.273	0.182	0.091	0.091	2.118	4.341
A07	PRPEFRPEFR	0.300	0.300	0.200	0.200	0.000	1.971	3.920
A08	PRPRRPFEPREFPERFPRFPRE	0.318	0.318	0.182	0.182	0.000	1.946	3.852
A09	PGFGRERPGPEGRPGPREP	0.211	0.316	0.053	0.158	0.263	2.149	4.436
A10	PGRFERFPGFRPRPRFPRPER	0.333	0.286	0.190	0.095	0.095	2.147	4.428
A11	PGRFPRPGPERFEPREFPR	0.318	0.318	0.182	0.182	0.000	1.946	3.852
A12	PRGRPRPGRFEPRFEPREPE	0.211	0.316	0.053	0.158	0.263	2.149	4.436
A13	PRGFPRPFFGPRFGERPER	0.333	0.286	0.190	0.095	0.095	2.147	4.428
A14	PRGFRFPRERFRPF	0.263	0.316	0.158	0.158	0.105	2.215	4.642
A15	PGRFPGRPRFPFRPREPR	0.300	0.300	0.100	0.200	0.100	2.171	4.503
A16	PGRFPRPRGFPRFRPE	0.263	0.263	0.211	0.105	0.158	2.249	4.754
A17	PRGPRFEGPRPRPEP	0.357	0.214	0.286	0.071	0.071	2.067	4.190
A18	PRGFPGRFPRGPRFRPERFPRE	0.333	0.333	0.167	0.056	0.111	2.071	4.203
A19	PGRFPRGEREPRPRF	0.312	0.312	0.188	0.062	0.125	2.127	4.367
A20	PRGFRGPRGEPRPRPERFE	0.267	0.400	0.067	0.133	0.133	2.073	4.207
A21	PGFRFPRPRPPEPRE	0.318	0.273	0.182	0.091	0.136	2.191	4.565
A22	PGRPRFPRPGPRFEGRFR	0.333	0.267	0.133	0.133	0.133	2.200	4.593
A23	PRGRFPRFPFERRFER	0.316	0.263	0.105	0.158	0.158	2.215	4.642
A24	PRFPFPRGEPRFEGR	0.267	0.267	0.200	0.133	0.133	2.257	4.779
A25	PGRFPGEPRFPGRE	0.214	0.286	0.143	0.143	0.214	2.271	4.826
A26	PGRFPGFRPRERFGRPE	0.294	0.235	0.176	0.118	0.176	2.257	4.780
A27	PGRPFRPFRPERERF	0.333	0.267	0.200	0.133	0.067	2.149	4.436
A28	PRGRFPRFEPRFERF	0.333	0.200	0.267	0.133	0.067	2.149	4.436
A29	PGRFEPRFPREPRE	0.286	0.286	0.143	0.214	0.071	2.182	4.538
A30	PGRFRFPGRFRPFPGRFE	0.278	0.222	0.278	0.056	0.167	2.171	4.504
A31	PGRFREREPRPRFR	0.429	0.214	0.143	0.143	0.071	2.074	4.211

No.	Encoding result	Probability of event occurrence					H	D
		R	P	F	E	G		
A32	PRFPRFPEFPFPREP	0.200	0.400	0.267	0.133	0.000	1.889	3.704
A33	PRGFPRPFPFP	0.182	0.455	0.273	0.000	0.091	1.790	3.458
A34	PGRFPRFPRFPERGRF	0.312	0.250	0.250	0.062	0.125	2.149	4.436
A35	PRFPFEPFRPFEFR	0.214	0.286	0.357	0.143	0.000	1.924	3.795
	Average	0.283	0.293	0.181	0.127	0.116	2.119	4.356

Analyze whether there is a significant difference in the DI between the experimental group and the control group. To study this difference, we employ non-parametric tests, specifically using the Mann-Whitney U test statistic for analysis. The results indicate that there are significant differences in the DI between the experimental group and the control group ($p < 0.05$). Further specific analysis reveals that the median DI of the experimental group is 4.436, which is significantly higher than that of the control group (3.888) ($p < 0.01$). Explanation: Compared to the design methods used by the control group, the experimental group's use of the motivation logic design method significantly increased cognitive activities during the design process, and these differences were statistically significant.

4.3 The output results of two coding schemes for design ideations

Now, by superimposing the codes that represent the design ideations of all participants in both the experimental and control groups, we can obtain two design solutions. The coding data for these two solutions are summarized in Table 5. From the codes presented in the table, the following observations can be made: (1) The control group's design solution represents a sports bra. In the coding of this solution, the majority of design ideations concentrate on the attributes of products and services related to sports. (2) The experimental group presents solutions beyond user expectations, which are rooted in motivational logic. This solution appeals to many users who are “unaware of their needs” for products and services that go beyond usual expectations, primarily including smart sports, chest care, and health consultation. The encoding of these two design solutions is the outcome of the evaluation experiment for this design method, reflecting the design solutions derived from different design approaches. It is evident that motivation logic design holds significant advantages in guiding the design of Smart PSS, and the two research hypotheses under H1 have been further validated.

Table 5
Two coding schemes based on different design methods

	Data in the control group	Data in the experimental group
Top 40 high-frequency encoded data	Comfort, softness, sponge support, wide sling design, fixed adjustment, helpful for sports, fashion, aerobic exercise, stability, flexibility, fitting material, smooth material, elastic material, wrapping, edge design, sweat absorbing material, comfort, vitality, prevent stuffiness, skin friendly, seamless, lightweight, removable chest pad, no steel ring, easy to clean, external wear, design aesthetics, ergonomic, personalized, adjustable device, heart rate detection, support structure, odor prevention, dressing, customization, simple structure, sporty lines, outdoor sports, high support, beautiful breasts.	Breast care, matching APP, services, breast enlargement, health management, automatic temperature control, monitoring of body indicators, intelligent reminders, monitoring of breast condition, real-time shape adjustment, body repair, wrapping, vibration, body shaping, weight loss, breast health, recording of exercise process, personalized exercise plan, helping with body management, preventing breast aging, breast beauty, pleasure, positioning function, intelligent action guidance, prevention of breast nodules, automatic size adjustment, breast lifting function, breast shaping, body monitoring, chest circumference, breast development, uploading fitness data, viewing body shape changes, chest shape data, maintaining chest status, dopamine color matching, enhancing exercise passion, community communication, disease detection, breastfeeding exercise.
Design solutions	Sports bra (mainly focusing on sports elements, leaning towards stability, sweat absorption and other properties)	smart sports bra (more diversified and creative, leaning towards smart sports and chest care attributes)

5 Discussions

5.1 Discussion on Different Design Methods

From the data of the protocol analysis experiment, it is evident that both the DI and the MII are significantly higher in the experimental group compared to the control group. Explanation: (1) When compared with other design methods learned by the participants, motivation logic design is capable of generating a greater number of high-quality ideas and thoughts during the design process. This reflects that motivation logic design methods have a more positive impact on how cognitive resources are allocated to explore various design schemes and ideas. Specifically, a high DI signifies that the design process encompasses a broader and more diverse array of cognitive activities. This extensive cognitive exploration aids in the creation of more innovative design solutions. Conversely, a low DI may suggest that the design process is more narrowly focused on specific cognitive activities, potentially limiting the innovation of the design scheme (Meslec et al., 2020). Thus, H1(a) has been confirmed. (2) In comparison to other design methods learned by the participants, motivation logic design results in a higher frequency of creativity per unit of time. This indicates that motivation logic design is more active and dynamic during the design process, enabling designers to generate more potential design solutions as they explore design problems. Therefore, when compared to other design methods learned by the participants, motivation logic design not only produces designs of good quality and originality, but also possesses the capacity to generate a greater number of creative ideas. Thus, H1(b) has been confirmed.

Design is a subjective and innovative activity. Protocol analysis methods, which focus on the design process and incorporate individual cognitive considerations, have been widely acknowledged (Gonçalves & Cash, 2021; Hatcher et al., 2018). This methodology effectively evaluates the quality of ideas in the design process by combining the DI and MII. These ideation evaluation methods are highly suitable for assessing and interpreting the verbal expressions of ideas captured through protocol analysis (Lee & Ostwald, 2022). A comprehensive study of design concepts necessitates identifying the operational variables and key conceptual components of design methods, modeling them based on atomic cognitive processes and structures, and correlating them with outcome indicators (Shah et al., 2003). In this paper, we adopt this approach to more accurately reproduce the process and results of motivation logic design. By enhancing its

argumentation strength through statistical analysis, we aim to demonstrate the advantages of the motivation logic design method in terms of both the quality and quantity of design innovation.

5.2 Motivation logic design for smart pss

From the S-O-R model, it is evident that the design focus of physical logic design centers on external objects (products), emphasizing their attractiveness, functionality, and other attributes to fulfill or stimulate the needs of organisms (Stimuli, S). Conversely, behavior logic design focuses on human behavioral responses (R), ensuring that products, services, or systems align with users' explicit needs, behaviors, and expectations. The motivation logic design proposed in this paper shifts focus to human motivation, examining users' more fundamental and implicit motivations from a first-principles perspective, rather than being constrained by the explicit needs and behaviors dictated by existing industries, technologies, products and services. Compared to behavior logic design, motivation logic design boasts an advanced starting point, broadening the design space and enhancing the design exploration level. These two factors—design space and design exploration level—are crucial indicators for assessing a design method and design theory (Shah et al., 2003). Consequently, motivation logic design is exceptionally suited to tackle the diverse challenges faced by Smart PSS design. It serves as the creative design theory and framework, facilitating the achievement of solutions that exceed user expectations. The fundamental difference between the experimental group and the control group lies in their design foundations: the experimental group is based on motivation logic, whereas the control group is rooted in explicit needs. This paper achieves the transition from explicit needs to implicit motivations through factor analysis, validating the research hypothesis H2, implementing the motivation logic design paradigm. Given the earlier starting point of motivation logic design, designers can identify more conflicting elements during the problem-construction phase, leading to superior design solutions. As Reiter-Palmon et al. (2023) argue, the greater the conflict among the elements retained in problem-solving, the more innovative and high-quality the solution becomes, increasing the likelihood of achieving solutions beyond user expectations. This result is also supported by this study, as evidenced in Table 5. Just as the evolution from behavioral psychology to cognitive psychology represents an inevitable historical and social progression, the development from behavior logic design to motivation logic design is also a result of the evolution of design paradigms.

In fact, designers who rely on the behavior logic paradigm also strive to achieve solutions beyond user expectations by uncovering users' underlying needs. Underlying needs refer to users' potential, implicit, and deeper needs that extend beyond their immediate awareness. These needs lie outside the scope of users' personal abilities, perspectives, and knowledge, representing aspects that users are unaware they need. Norman is a representative figure who believes that underlying needs may be linked to users' emotions, psychology, cultural background, values, or specific contexts (Norman, 2004; Zhou et al., 2024). While the concept of underlying needs resembles the motivation discussed in this paper, unfortunately, it may pose a limitation within the design paradigm. Behavior logic-based design fails to distinguish the boundary and transformation between explicit and underlying needs, making underlying needs akin to a "spiritual feeling" that is challenging to harness for specific design guidance. Some scholars have proposed exploratory design methods related to motivation, such as the Fogg Behavior Model (Fogg, 2025) and Persuasive Design (Whalen, 2011), but these methods lack a theoretical system and framework grounded in motivation logic. This paper clearly delineates the boundaries between motivation logic design, physical logic design, and behavior logic design, and establishes a design method rooted in motivation logic, demonstrating it as a novel and promising design paradigm.

6 Conclusions and prospects

To address the challenges posed by diversified product forms, ecologicalization, and the significant involvement of product stakeholders in Smart PSS, this paper proposes motivation logic design that builds upon physical and behavior logic designs. It demonstrates that motivation logic design represents a novel design paradigm and theory. This design offers superior design space and exploration potential, facilitating collaborative design innovation among technical engineers, product operators, end-users, and others. By addressing complex product forms and achieving a win-win

situation for multiple stakeholders, motivation logic design emerges as the theoretical framework for complex product design, such as Smart PSS, as well as for collaborative design. Furthermore, motivational logic design can transform product design solutions from traditional approaches focused on 'problem solving' and 'need satisfaction' to innovative solutions that exceed user expectations.

This paper demonstrates, through the think aloud protocol analysis experiment, that motivation logic design exhibits significant advantages in both the DI and the MII. When compared to other design methods known to the participants, motivation logic design is capable of generating more high-quality ideas and thoughts during the design process. Furthermore, it suggests that motivation logic design is more active and dynamic in the design process than other design methods known to the participants, enabling designers to explore design problems and produce more potential design solutions.

This paper acknowledges some shortcomings in its exploration of a new forward-looking design paradigm. (1) Motivation logic design still requires further research and application, and its effectiveness needs to be demonstrated through a wider range of cases. For instance, the paper currently only employs sports bras as design examples. Whether motivation logic design remains effective in guiding the design of other products and services necessitates additional practical cases for validation. (2) Additionally, some scholars have put forward the concept of cognitive design (Wertz & Moya, 2019). While cognitive design may offer a more pertinent explanation of the S-O-R model, this paper contends that cognitive design is too broad and impractical to serve as a supportive theory for design purposes. Consequently, motivation logic design is proposed due to the closer relationship between motivation and behavior. Future research by more scholars is needed to delve deeper into the interplay between these two concepts. (3) Given that motivation falls within the realm of cognition, future empirical research, such as utilizing electroencephalography, can be conducted to investigate the brain mechanisms underlying motivation.

Declarations

Ethical approval

All procedures performed in this study involving human participants were following the principles of the Declaration of Helsinki and its later amendments or comparable ethical standards. The authors received ethical approval (No. GDUTXS2024034) from the Academic Committee of Guangdong University of Technology on March 4, 2024. The experiment was conducted with the consent of participants, and explained the purpose and procedure of the study.

Informed consent

This experiment was conducted from March to May 2024. Before initiating the data collection, the researcher sought and obtained the consent of the participants for them to participate in the study. All participants voluntarily participated in the study in acceptance of the researcher’s assurance of anonymity and the use of their responses solely for academic purposes. All information is anonymized, and the submission does not include images that may identify any persons.

Funding

declaration

This study was supported by the Guangdong Province Social Science Planning Project under Grant GD25YYS52.

Author Contribution

Xiaohong Mo: conceptualization, data curation, methodology, visualization, writing-original draft.Zhikai Lv: data curation, methodology, writing-original draft.Ding-Bang: conceptualization, resources, supervision.Xian Yang: resources, supervision, writing-review & editing.

References

1. Ajzen I (1985) From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (11–39). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-69746-3_2
2. Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–211. https://doi.org/https://doi.org/10.1016/0749-5978(91)90020-T
3. Ajzen I (2012) Handbook of Theories of Social Psychology: Volume 1 AU - Ajzen. Icek, London
4. London SAGE Publications Ltd
5. Aleikish K, Nøland JK, Øyvang T (2025) Synergistic Meta-Heuristic Adaptive Real-Time Power System Stabilizer (SMART-PSS). IEEE Open Access J Power Energy 12:36–45. https://doi.org/10.1109/OAJPE.2025.3532768
6. Bamberg S, Ajzen I, Schmidt P (2021) Travel Mode Choice as Reasoned Action. Int Encyclopedia Transp 63–70. https://doi.org/https:// doi.org/10.1016/B978-0-08-102671-7.10408-7
7. Beckmann J, Heckhausen H (2018) Motivation as a Function of Expectancy and Incentive. In J. Heckhausen & H. Heckhausen (Eds.), *Motivation and Action* (163–220). Springer International Publishing. https://doi.org/10.1007/978-3-319-65094-4_5
8. Berridge K, Kringelbach M (2015) Pleasure Systems in the Brain. Neuron 86:646–664. https://doi.org/10.1016/j.neuron.2015.02.018
9. Brady PA (2007) Golding's prepubescent main characters—Ralph, Piggy, Jack, Roger, and Simon—as allegories juxtaposed with Abraham H. Maslow's hierarchy of needs. *Dissertations & Theses Gradworks*
10. Cortinas M, Cabeza R, Chocarro R, Villanueva A (2019) Attention to online channels across the path to purchase: An eye-tracking study. Electron Commer Res Appl 36:100864. https://doi.org/https://doi.org/10.1016/j.elerap.2019.100864
11. Damasio AR (2001) Emotion and the Human Brain. Ann N Y Acad Sci 935(1):101–106. https://doi.org/https://doi.org/10.1111/j.1749-6632.2001.tb03475.x
12. Deci EL, Ryan RM (1985) Intrinsic Motivation and Self-Determination in Human Behavior. Contemp Sociol, 3(2)
13. Deci EL, Ryan RM (2000) The What and Why of Goal Pursuits: Human Needs and the Self-Determination of Behavior. Psychol Inq 11(4):227–268. https://doi.org/10.1207/S15327965PLI1104_01
14. Eisele P (2008) Bauhaus. In M. Erlhoff & T. Marshall (Eds.), *Design Dictionary: Perspectives on Design Terminology* (39–42). Birkhäuser Basel. https://doi.org/10.1007/978-3-7643-8140-0_20
15. Fiorineschi L, Frillici FS, Rotini F (2022) Refined metric for a-posteriori novelty assessments. J Eng Des 33(1):39–63. https://doi.org/10.1080/09544828.2021.1976397
16. Fitts PM (1992) The information capacity of the human motor system in controlling the amplitude of movement. 1954. *Journal of Experimental Psychology. General*, 121 3, 262–269
17. Fogg B (2025) 2024-3-4). Fogg Behav Model Retreved 2025.3.4 from www.behaviormodel.org
18. Gonçalves M, Cash P (2021) The life cycle of creative ideas: Towards a dual-process theory of ideation. Des Stud 72. https://doi.org/10.1016/j.destud.2020.100988
19. Hatcher G, Ion W, Maclachlan R, Marlow M, Simpson B, Wilson N, Wodehouse A (2018) Using linkography to compare creative methods for group ideation. Des Stud 58:127–152. https://doi.org/10.1016/j.destud.2018.05.002

20. Hernandez NV, Shah JJ, Smith SM (2010) Understanding design ideation mechanisms through multilevel aligned empirical studies. Des Stud 31(4):382–410. https://doi.org/10.1016/j.destud.2010.04.001
21. Huddleston PT, Behe BK, Driesener C, Minahan S (2018) Inside-outside: Using eye-tracking to investigate search-choice processes in the retail environment. J Retailing Consumer Serv 43:85–93. https://doi.org/https://doi.org/10.1016/j.jretconser.2018.03.006
22. Koutstaal W (2024) A New Test for Assessing Creative Flexibility of Perceptual Interpretation: The Figural Interpretation Quest. Psychol Aesthet Creativity Arts. https://doi.org/10.1037/aca0000644
23. Koutstaal W, Brown L, Lu KB, Posson K (2024) Beyond Openness: A Variety of Creative Experiences Increases Flexibility and Originality of Visuospatial Divergent Thinking. Creativity Res J. https://doi.org/10.1080/10400419.2023.2300575
24. Lee JH, Ostwald MJ (2022) The relationship between divergent thinking and ideation in the conceptual design process. Des Stud 79:101089. https://doi.org/https://doi.org/10.1016/j.destud.2022.101089
25. Lee SO, Hyun SS, Wu Q (2024) The effects of motivation and prior knowledge on wine consumers' decision-making process: using an extended model of goal-directed behavior. Int J Contemp Hospitality Manage 36(8):2887–2908. https://doi.org/10.1108/IJCHM-08-2023-1283
26. Li Y, Hu B, Tang C, Yang X (2025) Research on Interactive Efficiency and Experience of Intelligent Education Platform. Int J Human–Computer Interact 1–17. https://doi.org/10.1080/10447318.2024.2433841
27. Liao C (2025) The role of virtual reality in enhancing behavioral empathy: exploring cognitive absorption, engagement, and emotional moderation using multivariate methods. Humanit Social Sci Commun 12(1):995. https://doi.org/10.1057/s41599-025-05334-5
28. Licklider JC (1960) Man-computer symbiosis. IRE Trans Hum Factors Electron (1), 4–11
29. Lin C, Chen Y (2025) Motivation mechanism: a study of behavioral competence diversity toward exploitative and exploratory innovation in open interdisciplinary teams. Qual Quant 59(1):457–476. https://doi.org/10.1007/s11135-024-01930-w
30. Lou Y (2023) Human Creativity in the AIGC Era. She Ji-the J Des Econ Innov 9(4):541–552. https://doi.org/https://doi.org/10.1016/j.sheji.2024.02.002
31. Luchini S, Kenett YN, Zeitlen DC, Christensen AP, Ellis DM, Brewer GA, Beaty RE (2023) Convergent thinking and insight problem solving relate to semantic memory network structure. Think Skills Creativity 48. https://doi.org/10.1016/j.tsc.2023.101277
32. Mai X (2022) An Empirical Study of College English PAD Class Based on Self-Determination Theory. Int J Soc Sci Stud 10(1):45–50
33. Mehrabian A, Russell J (1974) An approach to environmental psychology. MIT Press
34. Meslec N, Graff D, Clark MA (2020) Increasing team ideation by sequencing the task type and content. Des Stud 70. https://doi.org/10.1016/j.destud.2020.100947
35. Moggridge B, Atkinson B (2007) Designing interactions, vol 17. MIT press Cambridge
36. Monferdini L, Tebaldi L, Bottani E (2025) From Industry 4.0 to Industry 5.0: Opportunities, Challenges, and Future Perspectives in Logistics. Procedia Comput Sci 253:2941–2950. https://doi.org/https://doi.org/10.1016/j.procs.2025.02.018
37. Naiseh M, Al-Thani D, Jiang N, Ali R (2023) How the different explanation classes impact trust calibration: The case of clinical decision support systems. Int J Hum Comput Stud 169:102941. https://doi.org/https://doi.org/10.1016/j.ijhcs.2022.102941
38. Nayak S, Pereira V, Kazmi BA, Budhwar P (2024) To Buy or Not to Buy? Exploring Ethical Consumerism in an Emerging Market—India. J Bus Ethics 191(4):811–835. https://doi.org/10.1007/s10551-024-05670-7
39. Neher A (1991) Maslow's Theory of Motivation. J Humanistic Psychol 31(3):89–112

40. Norman D (2004) Emotional Design: Why We Love (or Hate) Everyday Things *Emotional Design* (287). New York: Basic Books
41. Orth UR, Wirtz J (2014) Consumer Processing of Interior Service Environments: The Interplay Among Visual Complexity, Processing Fluency, and Attractiveness. J Service Res 17(3):296–309. https://doi.org/10.1177/1094670514529606
42. Orwig W, Edenbaum ER, Greene JD, Schacter DL (2024) The Language of Creativity: Evidence from Humans and Large Language Models. J Creative Behav. https://doi.org/10.1002/jocb.636
43. Perugini M, Bagozzi RP (2004) The distinction between desires and intentions. Eur J Social Psychol 34(1):69–84. https://doi.org/https://doi.org/10.1002/ejsp.186
44. Pilatin A, Dilek Ö (2024) Investor intention, investor behavior and crypto assets in the framework of decomposed theory of planned behavior. Curr Psychol 43(2):1309–1324. https://doi.org/10.1007/s12144-023-04307-8
45. Reiter-Palmon R, Leone S, Schreiner E (2023) Conflicting Problem Representations and Creativity: Effects on Problem Construction. Creativity Res J. https://doi.org/10.1080/10400419.2023.2234720
46. Schmidt P, Gordoni G, Ajzen I, Beuthner C, Davidov E, Silber H, Steinmetz H, Weiß B (2022) Twitter Users' Privacy Behavior: A Reasoned Action Approach. Social Media + Soc 8(3):20563051221126085. https://doi.org/10.1177/20563051221126085
47. Shah JJ, Smith SM, Vargas-Hernandez N (2003) Metrics for measuring ideation effectiveness. Des Stud 24(2):111–134. https://doi.org/https://doi.org/10.1016/S0142-694X(02)00034-0
48. Sharma E, Bagozzi RP, Mahmoud R (2024) Consumer reactions to direct-to-consumer advertising: the model of goal-directed behavior, moral identity, and self-discrepancy regulation. J Mark Theory Pract. https://doi.org/10.1080/10696679.2024.2380715
49. Song H (2025) Error detection of industrial design product appearance dimensional based on machine vision. Int J Prod Dev 29(1):100–119. https://doi.org/10.1504/IJPD.2025.144853
50. Suijkerbuijk S, Nap HH, Ijsselsteijn WA, Minkman MMN, de Kort YAW (2024) I already forgot half of it' - Interviewing people with dementia for co-designing an intelligent system. Hum Comput Interact 39(3–4):225–256. https://doi.org/10.1080/07370024.2023.2240791
51. Tan L, Luhrs M (2024) Using Generative AI Midjourney to enhance divergent and convergent thinking in an architect's creative design process. Des J 27(4):677–699. https://doi.org/10.1080/14606925.2024.2353479
52. Taylor SD, Bagozzi RP, Gaither CA (2005) Decision making and effort in the self-regulation of hypertension: Testing two competing theories. Br J Health Psychol 10(4):505–530. https://doi.org/https://doi.org/10.1348/135910704X22376
53. Tenner E (2015) The design of everyday things by donald norman. Technol Cult 56(3):785–787
54. Wertz AE, Moya C (2019) Pathways to cognitive design. *Behavioural Processes*, 161, 73–86. https://doi.org/https://doi.org/10.1016/j.beproc.2018.05.013
55. Whalen J (2011) Persuasive design: Putting it to use. Bull Am Soc Inform Sci Technol 37(6):16–21. https://doi.org/https://doi.org/10.1002/bult.2011.1720370607
56. Wright R, Brinkmann K, Gendolla G (2013) Motivation. Oxf Bibliographies Online: Psychol. https://doi.org/10.1093/obo/9780199828340-0039
57. Wu R, Fan J, Tang C, Yang X (2025) Interaction-based creative thinking research and its application in artistic creation. Think Skills Creativity 56:101750. https://doi.org/https://doi.org/10.1016/j.tsc.2024.101750
58. Wu Y, Acharya K (2024) Breaching-through-Service: Accounting and Shaping Social Order with Service Design. Des Issues 40(4):54–66. https://doi.org/10.1162/desi_a_00780
59. Yang X, Yang B, Tang C, Mo X, Hu B (2024) Visual Attention Quality Research for Social Media Applications: A Case Study on Photo Sharing Applications. Int J Hum Comput Interact 40(14):3827–3840.

https://doi.org/10.1080/10447318.2023.2201556

60. Yang. X, Zhang. C, Li Y, Tang C, Liang P (2024) Dynamic user profile construction and its application to smart product-service system design: A maternity-oriented case study. Expert Syst Appl 249:123772. https://doi.org/https://doi.org/10.1016/j.eswa.2024.123772
61. Yildiz Durak H (2025) Impact of ML-LA feedback system on learners' academic performance, engagement and behavioral patterns in online collaborative learning environments: A lag sequential analysis and Markov chain approach. Educ Inform Technol 30(2):2623–2644. https://doi.org/10.1007/s10639-024-12911-9
62. Youn H, Baek JS (2024) Assemblage-based stakeholder analysis in design: a conceptual framework through the lenses of post–anthropocentrism. CoDesign-International J CoCreation Des Arts 1–22. https://doi.org/10.1080/15710882.2024.2358966
63. Zhang B, Li J, Zhou J, Chow L, Zhao G, Huang Y, Ma Z, Zhang Q, Yang Y, Yiu CK, Li J, Chun F, Huang X, Gao Y, Wu P, Jia S, Li H, Li D, Liu Y, Yao K, Shi R, Chen Z, Khoo BL, Yang W, Wang F, Zheng Z, Wang Z, Yu X (2024) A three-dimensional liquid diode for soft, integrated permeable electronics. Nature. https://doi.org/10.1038/s41586-024-07161-1
64. Zhang X, Pi Z, Lv Y, Hu W (2025) Promoting group creative performance by enhancing motivation to cooperate: Mechanisms at the behavioral and neural levels. Think Skills Creativity 57:101815. https://doi.org/https://doi.org/10.1016/j.tsc.2025.101815
65. Zhou Y, Xiang W, Jiang H, Zuo K, Lu Y (2024) How do emotions evolve? The effect of emotions in the interactive scenes of a new product trial. Des J 27(5):934–953. https://doi.org/10.1080/14606925.2024.2372178