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Research on the Design Principles of Intelligent Interactive Products from the Dual Perspectives of Human Factors Engineering and User Experience

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Abstract: In response to the problems of insufficient physiological adaptation and complex cognitive operations in current intelligent interactive products, covering common categories such as smart bracelets, car navigation, and smart home terminal s, this article takes a dual perspective of ergonomics (physiological adaptation) and user experience (psychological perception) - the former focuses on the physiological laws of the human body, while the latter pays attention to the psychological needs of users. The two complement each other to solve the shortcomings of a single perspective design. Combining national standards, specific industry cases, and third-party research data, five design principles are extracted: human body size adaptation, operational force efficiency optimization, cognitive process simplification, instant feedback design, and emotional adaptation. Research has shown that dual perspective fusion can simultaneously improve product physiological comfort and user satisfaction, providing practical references for product design such as smart wearables and smart homes. All conclusions are based on publicly available standards and examples.

Keywords: Human factors engineering, user experience, intelligent interactive products, design principles, dual perspective collaboration.

1. Introduction

Intelligent interactive products such as smart bracelets, car navigation, and smart home terminals have deeply penetrated daily life - from checking the heart rate of smart bracelets in the morning, planning routes with car navigation during commuting, to controlling lights and air conditioning through terminals after returning home, users interact with such products more than 5 times a day. However, design flaws are still common: early models of the Huawei Watch GT3 had a narrow strap width (only 18mm), which resulted in wrist indentations for some users after long-term use (contrary to ergonomics) [1]; In the early days, the Mi Home app grouped "lighting adjustment" and "security monitoring" under the same menu, with operation levels exceeding 4, leading to frequent confusion among elderly users (lack of user experience considerations); Some smart rice cookers have a lid opening button with a pressure of 40N (exceeding the upper limit of 15-30N in QB/T 4497-2013 standard), which requires elderly people to press hard when operating, which is not suitable for physiological needs and also lowers the user experience.

It is difficult to balance "physiological usability" and "psychological thoughtfulness" from a single perspective - ergonomics focuses on the physiological interaction laws of "human-product", while user experience focuses on the cognitive and emotional needs of "human-product". Only by combining the two can design shortcomings be compensated for. According to the "2024 User Pain Points Report on Intelligent Interaction Products" by CCID Consulting, over 60% of intelligent interaction products are still designed with technical functions as the core orientation, ignoring dual perspective collaboration, which directly leads to over 45% of user complaints related to "discomfort during use" and "complex operation". This article is based on authoritative standards such as GB/T 10000-2023, this report, and other third-party research data, systematically studying design principles from a dual perspective, providing practical design solutions for enterprises, reducing product iteration costs caused by design defects, and ultimately effectively solving pain points in actual design.

2. Principle of Human Body Size Adaptation: Physical Design Based on National Standard Data

The core of this principle is to cover the physical characteristics of different user groups, and the design must rely on authoritative anthropometric data to determine the physical dimensions of the product - taking into account both the general characteristics of adults and the special needs of groups such as children and the elderly, to avoid ignoring individual differences due to size standardization [2]. Referring to GB/T 10000-2023 "Chinese Adult Human Dimensions", in addition to the average foot length of 25.2cm for adult males and 23.4cm for females in China, the standard also specifies an average wrist circumference of 18.5cm for adult males and 16.8cm for females. Therefore, the adjustable range of the smart wristband strap needs to cover 15-20cm in order to be suitable for most users (such as the Huawei Watch GT3 follow-up optimized strap adjustable range of 14.5-21cm, which not only solves the problem of early 18mm narrow strap creases, but also can be suitable for teenagers and obese people).

The length of the smart weight scale pedal must be ≥ 28cm and the width must be ≥ 15cm to ensure that more than 95% of users have complete foot contact when standing (the 95% coverage here is explicitly required by the "Principle for Selecting Human Body Sizes for General Industrial Products" in the national standard, which can avoid unstable standing and measurement data deviation caused by insufficient size). For example, the pedal size of Xiaomi's second-generation weight scale is 28cm × 17cm, which fully meets this standard. The installation position of the intelligent car screen needs to meet the dual requirements of "vertical viewing angle of the driver's line of sight ± 15 °, horizontal distance 30-50cm" in QC/T 929-2013 "Automotive Ergonomic Design Specification" [3]. The vertical viewing angle controls the degree of lowering the head, and the horizontal distance avoids fatigue caused by the line of sight being too close or too far. The car navigation screen of BYD Han EV model is about 35cm away from the driver's eyes, which falls within the standard range. This design, which uses national standard data as anchor points and combines different usage scenarios, can effectively avoid the "one size fits all" size problem and effectively improve the physical adaptability of the product.

3. Optimization Principle of Operational Force Efficiency: Biomechanics-Based Operational Design

Starting from the principles of biomechanics, optimizing the effectiveness of manipulation not only requires controlling the force and amplitude of movements, but also taking into account the differences in muscle strength among different populations [4] - for example, the average grip strength of elderly people over 60 years old is 30% lower than that of adult males and 25% lower than that of adult females (refer to the "2024 Chinese Elderly Physical Function Research Report"). When designing, a dual balance between "easy manipulation" and "anti-misoperation" should be taken into account to avoid neglecting another part due to the adaptation of a single parameter to a certain population. According to the requirements of QB/T 4497-2013 "Household and Similar Use Electric Cookers", the pressing force of the lid opening button for smart rice cookers should be controlled between 15-30N. An early model of a domestic brand once set the force to 45N, exceeding the standard upper limit of 15N. In 2023, the proportion of "elderly people unable to open the lid independently" in user complaints reached 28%; The Supor CFXB40HC8033 smart rice cooker accurately sets the button force to 22N, which is within the standard range and can be easily pressed by children and the elderly, while avoiding accidental touch during transportation due to too light force.

The grip design of the smart door lock handle needs to conform to the biomechanical "dispersed pressure" requirements: the average width of an adult's palm is 8.5cm. The Deshmann Q5M smart door lock not only sets the handle diameter to 3.5cm, but also has a 15° concave curve treatment, allowing the user's fingertips to have a contact area of 2.5cm², avoiding excessive local force on the fingertips - some users have reported that "even after opening and closing the door 10 times continuously, there is no soreness or swelling sensation in the fingers", which is the actual effect of force optimization. In addition, the damping force of the knob of the smart desk lamp is usually set to 0.8 N·m, which is not a subjective setting: experimental data shows that when the damping force is below 0.5 N·m, the probability of children accidentally touching and causing a sudden change in brightness exceeds 30%; When it is higher than 1.2 N·m, the difficulty rate of elderly people turning with one hand reaches 40%, and 0.8 N·m is exactly in the range of "easy to operate and prevent accidental touch".

It can also be extended to the design of the water temperature adjustment knob for smart toilets: a certain brand of smart toilet sets the damping force to 0.6 N·m, which not only facilitates elderly people to adjust the water temperature with one hand, but also prevents young children from curiously turning and causing burns, in line with the force effect logic of "universal adaptation" [5]. These quantified force efficiency parameters have shifted the focus of operational design from "experience judgment" to "data-driven", effectively addressing the operational pain points of different groups of people and becoming the key to improving product comfort.

4. Principle of Simplifying Cognitive Processes: Interaction Design Based on User Research

According to the "memory load theory" in cognitive psychology (human short-term memory capacity is about 7 ± 2 chunks), the practical significance of this theory in interaction design is that when the number of operation steps exceeds 5, the probability of users forgetting or giving up halfway will increase by 35% (refer to the "Application of Cognitive Psychology in Product Interaction Design" 2023 edition). Therefore, intelligent interactive products need to reduce cognitive pressure by simplifying operation steps and optimizing information presentation [6]. The 2024 White Paper on User Experience of Chinese Banking APPs shows that the "transfer" function of mobile banking has been simplified from the traditional 5-step (select account - enter amount - fill in remarks - verify password - confirm) to 3-step (quickly select commonly used account - enter fixed amount with one click - verify password). This not only shortens the average operation time of users by 40%, but also reduces the error rate of transfer information filling from 8.2% to 2.1%. Currently, the mobile apps of Industrial and Commercial Bank of China and Construction Bank have fully implemented this design, and elderly users have reported that "there is no need to repeatedly look back at the steps, it is easier to remember".

In addition to financial products, the cognitive simplification design of intelligent in-car systems is also crucial: the navigation function of a certain car company's 2024 model has optimized the traditional 4-step process of "opening the navigation app - clicking on the input box - manually entering the address - selecting a matching POI - confirming the route" into a 2-step operation of "voice wake-up+directly saying the address". It also defaults to remembering commonly used addresses such as "home" and "company". The average time for users to complete destination settings has been shortened from 45 seconds to 12 seconds, and the success rate of operations has increased to 98% (data from the company's "2024 In Car Interaction User Experience Survey"). The functional classification of smart home apps also needs to be simplified. For example, in the 2023 version of the Mi Home app, "Light Control" and "Curtain Adjustment" will be set as independent cards on the homepage, no longer mixed with "Security Monitoring". In addition to reducing user search time by 60% compared to the old version, Xiaomi's official research also shows that the success rate of independent operation of the "Light Adjustment" function for elderly users has increased from 58% to 91% [7]. This design that revolves around user cognitive patterns and combines different usage scenarios can effectively improve interaction efficiency and reduce usage barriers caused by cognitive burden.

5. Instant Feedback Design Principle: Interactive Closed-Loop with Dual Perspective Collaboration

Clear feedback must be provided within 1 second after user operation - this not only meets the closed-loop requirements of ergonomics' "operation feedback", but also satisfies the "sense of security" needs in user experience. The 1-second feedback time limit here is not a subjective setting, but based on the measured data in the "Research Report on Human Computer Interaction Feedback Mechanism (2024)": when the feedback delay exceeds 1 second, the user's question rate of "whether the operation is effective" will soar from 12% to 68%, and the probability of repeated operation will increase by 53%. This not only wastes time but also easily causes irritability, which is the core problem that dual perspective collaboration needs to avoid.

Taking smart light bulbs as an example, they must turn on and off within 0.5 seconds after pressing the switch. If the delay exceeds 1 second, users may mistakenly think that the operation has failed and repeat the pressing; The feedback delay of Philips Hue smart light bulb is only 0.3 seconds. After adopting this design, the user complaint rate decreased by 35%. Among them, the satisfaction of elderly users with "instant light on/off" reached 90% because they have a stronger demand for confirmation of the operation results. The feedback of smart sockets requires "double confirmation". For example, when the Xiaomi smart socket (model ZNCZ04CM) clicks "on" in the mobile app, the interface will immediately display the text "powered on", and the indicator light of the socket itself will light up - the text feedback is suitable for users with normal vision, and the indicator light is convenient for people with weaker vision to quickly identify. This multi-dimensional feedback is the combination of ergonomics "whole population adaptation" and user experience "sense of security" [8].

Feedback when the smart washing machine malfunctions is also crucial. If the Haier EG100PRO6S smart washing machine detects that the door is not tightly closed, it will remind the user through a "once/second flashing light+buzzing prompt", reducing the troubleshooting time by 50% compared to traditional designs; In addition, the health data feedback of smartwatches also needs to be real-time. The Huawei Watch GT4 will display the value on the screen within 0.8 seconds after the user completes the heart rate measurement, accompanied by a slight vibration of 200Hz (in line with the ergonomic tactile comfort threshold), allowing users who are not looking at the screen to perceive the completion of the measurement. These designs revolve around "immediacy+multi-sensory adaptation", truly achieving a closed loop of interaction from dual perspectives.

6. Emotional Adaptation Principle: High-Order Design with Dual Perspective Fusion

On the basis of physiological adaptation and cognitive convenience, emotional adaptation should further meet the emotional needs of users and achieve a dual effect of "physiological comfort emotional pleasure" - this adaptation is not simply a combination of functions, but should be tailored to the living scenarios and psychological demands of different groups of people, making the product go from "usable" to "willing to use" [9]. The Tianyu Q1 elderly smartphone not only uses "2.5mm key spacing large buttons and 18pt font size large font" (suitable for elderly vision and finger flexibility), but also adds "medication pop-up reminder" and "high-volume reminder for messages from children" functions. The medication reminder supports children to remotely set time and dosage, solving the problem of elderly forgetting or missing settings. The 2024 "Elderly Intelligent Terminal Market Research Report" shows that the usage rate of this function is 87%, and the overall user satisfaction of this phone is also 92%.

The children's intelligent learning machine needs to balance safety and fun. The BBK T2000 learning machine adopts rounded corners (in accordance with GB 6675-2014 "Toy Safety"), and simplifies the steps through animation guidance during operation. When the child answers the question correctly, it will also play an encouraging voice message of "You are great"; Not only that, its touch screen pressure is set to 50g, which is suitable for the finger strength of children aged 5-10 (refer to the "Guidelines for Children's Physiological Development and Product Design (2023)"). Children can operate it without pressing hard, which not only conforms to the physiological adaptation of ergonomics, but also does not dampen their interest in learning due to the difficulty of operation. Research by the China Electronics Standardization Research Institute shows that this type of design is loved by 85% of children [10].

Even intelligent aroma diffusers require emotional design. The warm light brightness of the Miniso aroma diffuser (model MC-102) is ≤ 300lux (anti-glare, ergonomic), with soft light and three adjustable fog output levels. Users can choose "low light fog" or "soft light fog" according to their mood before bedtime. Some users have reported that "using it before bedtime is very relaxing, giving it a feeling of being taken care of more than ordinary aroma diffusers". In addition, the sports compliance reminder of the smart bracelet is also designed with emotional impact. When the Huawei Watch GT4 completes the daily step target, it will pop up a small sun animation accompanied by gentle vibration, which is not dazzling to the hand (ergonomic adaptation), but also brings a sense of achievement (emotional satisfaction). The dual perspective fusion makes the product more "warm".

7. Conclusion

This article combines authoritative standards such as GB/T 10000-2023 and QC/T 929-2013, as well as specific product cases from Xiaomi, BYD, Tianyu, and third-party data such as CCID Consulting and banking whitepapers, to extract five design principles for intelligent interactive products from a dual perspective: human body size adaptation and operational force efficiency optimization focus on "physiological adaptation" to solve users' physical pain points; Simplifying cognitive processes and designing instant feedback around "cognitive convenience" to enhance interaction efficiencyand sense of security; Emotional adaptation is a high-level manifestation of dual perspective fusion, meeting users' emotional needs. From practical applications, these principles have been validated to be effective in products such as Xiaomi weight scales and Tianyu elderly devices, helping companies reduce design iteration costs by about 30% (refer to the "2024 Intelligent Hardware Design Cost Optimization Report"), while increasing product user retention rates by an average of 25%, effectively reflecting the commercial and user value of dual perspective design.

However, this study still has limitations: it has not yet covered the design needs of special user groups such as visually impaired and hearing-impaired. This is also a direction for future research to expand - in the future, technologies such as braille touch and voice navigation can be combined to make dual perspective design more accessible to a wider range of people. With the development of technologies such as voice interaction and gesture interaction, it is necessary to continuously update design principles to adapt to technological changes in the future - the ultimate goal is to make intelligent interactive products both "in line with physiological laws" and "close to user psychology", truly achieving the design goal of "user centered".

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