



Intelligent Product Design with Natural Interaction

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Abstract. This paper analyzes intelligent products' design from the perspective of enhancing the user experience to understand natural interaction in intelligent products' development. According to the people-oriented natural interaction characteristics, this paper analyzes intelligent products' development and discusses the future development trends. From the perspective of information processing psychology, this paper analyzes why "intelligent speakers" are so popular and clarifies the situational factors in intelligent product design based on situational awareness theory, which leads to the natural interaction direction of intelligent product design. Finally, a case of an intelligent speaker's design process is presented. The case shows that the core of intelligent product design is to reduce user information transformation workload on the one hand. On the other hand, it predicts the user's action or the result that the user wants to produce. The intelligent product should respond to users' unexpressed needs in advance and provide users with a more humanized and personalized user experience.

Keywords: Natural interaction · Intelligent products · User experience · Situational awareness

1 Introduction

Since the new century, we have experienced the explosive growth of scientific and technological achievements. The computer and Internet technologies mature gradually for the increasing demand for high-quality life in health, safety, convenience, and comfort. Most people worldwide have passed the era of not having enough food and warm clothes. Consumers are no longer satisfied with the essential functions of products; they prefer a more convenient, efficient, and high-quality, time-saving life [1]. Pushed by the Internet of things technology, intelligent products became popular. The wide application of intelligent products had become the new trend. It brings new challenges and new opportunities. According to expert analysis [2], China's intelligent product industry chain is not yet mature, and it is still in the growth stage. There is also a lack of unified industry standards. At present, most smart home products are simply equipped with WIFI connectivity or embedded chip for hardware improvements. Many do not realize real intelligent learning. Moreover, due to the numerous platforms and different ways of connecting smart products to different services, users need to download

multiple apps to control different smart products. Many of these products do not systematically realize functions such as interconnection between smart products, making the user experience worse. Finally and most importantly, intelligent product designers and manufacturers misunderstand the essence of intelligent product design. They focus their product development on technology upgrading and fail to accurately grasp users' real needs.

Except for natural creations, all human-created artifacts are made for "use" [3]. Product design is essentially a creative act of artificial creation, which is to "create a more reasonable way to live (use)" [4]. According to Norman, a successful product can be described by a three-legged stool. Technology, marketing, and user experience support the right product [5]. Therefore, the focus of intelligent product design is not only on technology upgrading but also on user experience for a more comfortable, convenient, and natural life. In terms of research on intelligent product design, Cui et al. pointed out that product design in the intelligent era should meet the needs of users, design the operation mode that is easy for users to understand and master, and achieve barrier-free man-machine communication [6]; Song Fenglin introduced that the purpose of intelligence is to simplify operation steps and realize efficient application through complex structures, in which intelligent products have thinking ability is the core of its intelligence[7]; In the product design research based on user experience system, Mu Feng et al. also mentioned that design should communicate with people [8]. To enhance the user experience and change the user's very stiff feeling brought by the current intelligent products, intelligent products design should pay attention to the design of interaction mode between people and products to make it more natural. In the research on the interaction mode of intelligent products, Li Shiguo introduced that the design of interaction system should follow the principle of acceptability, that technology should adapt to people's lifestyle, and emphasized that it is more appropriate for people to use what technology to do what they want under what conditions [9]. Therefore, exploring natural interaction in intelligent products can further clarify intelligent products' core design direction.

2 Concept of Natural Interaction

Natural interaction is considered to be a kind of experience. People can naturally communicate through gestures, language expressions, behaviors, and actions, and they can also understand the world through watching and operating [10]. Now users are allowed to communicate with technology and machines to interact with the real world in daily life, named human-computer natural interaction. It is also called a natural user interface. This concept first originated from the research field of human-computer interaction. The user operates the computer through the most natural mode, such as action, gesture, language, etc., to get rid of the mouse and keyboard [11].

In product design, natural interaction means that people communicate and operate products through voice, action, behavior and other communication means in pre-language society. But in the actual interaction process, people may use "unnatural" actions or behaviors derived from life skills to interact with products. It mainly refers to learning and using abstract symbols such as text and graphics, including the acquired

learning of remote control graphics rules and the learning and interactive interface with a smartphone. This kind of interactive way still belongs to the natural interaction behavior. Thus, natural interaction also derives another meaning: people interact naturally with products through their skills and habits that grasp daily life [12] (see Fig. 1).

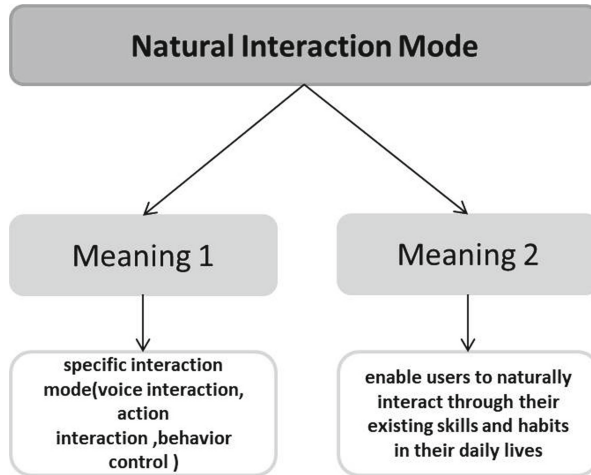


Fig. 1. Two layers of meaning of natural interaction.

Don Norman [13], in his book “Design for Future Products,” mentioned that the direction of future design is to “naturally” solve the problem of communication between users and products through natural interaction. Natural interaction mode studies the interaction mode between users and products, including the “natural” operation mode of users and the appropriate feedback mode.

3 Natural Interaction and Intelligent Product Design

Human-computer natural interaction can be divided into explicit human-computer natural interaction and implicit human-computer natural interaction: the former refers to the device system passively responds to the user’s active command operation mode corresponds to the user’s natural behavior in daily life. The latter means that the device system actively identifies and understands the user behavior and then acts the understood information on the human-computer interaction process [14]. This is the process that the machine adapts to the human. In this case, users needn’t pay too much attention to the interaction process and needn’t overthink using the device system either.

In the specific use scenarios of intelligent products, users and products have explicit natural interaction and implicit natural interaction (see Fig. 2). Explicit natural interaction means that intelligent products passively respond to the user’s active demand, such as the user says “light on” command by voice, and then the light is on accordingly. Implicit natural interaction means that intelligent products predict users’ unexpressed demands and respond to users’ demands in advance. For example, when users get up from their bed at night, the smart light nearby will automatically turn.

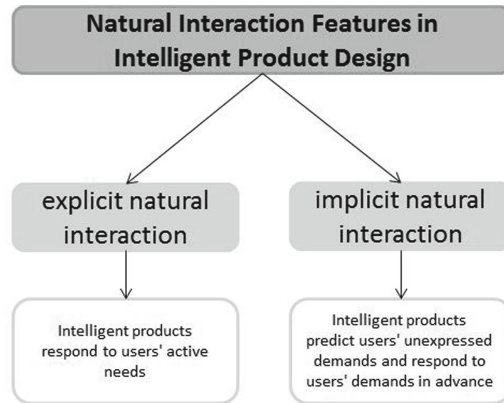


Fig. 2. Natural interaction characteristics in intelligent product design.

3.1 Explicit Natural Interaction

The core of explicit natural interaction is the design of the user's "natural" way of using a product. The focus is to observe the user's subconscious behavior to achieve its purpose in a specific use situation. As Don Norman once said in "Useable Design, "knee-jerk activity is quick and automatic and requires no effort" [15].

Information Processing Psychology

Information processing psychology is generated in the late 1950s. It emphasizes that cognition is the process of transforming, simplifying, storing, extracting, and using sensory information. Its activities include pattern recognition, attention, memory, strategy, knowledge representation, concept formation, problem-solving, judgment, reasoning, speech, and cognitive development [16].

Analysis of the Reasons for the Popularity of "Intelligent Speakers"

The gradual maturity and development of technology have brought voice interaction, gesture interaction, and other interactive ways. Smart home appliances can automatically perceive their own state and perceive the surrounding environment, automatically control and receive all kinds of instructions from users. In just a few years, a wide variety of intelligent household appliances are emerging on the market. Among them, the smart speaker market is scorching. The most significant difference between smart speakers and traditional speakers is the function of human-computer interaction. Voice interaction is the core of smart speakers. Researchers and relevant institutions have conducted in-depth research on voice interaction, making smart speakers understand human language to the maximum extent.

The reason why voice interaction is so popular with users is that voice interaction returns to human nature. Hence, it is primarily "natural" for users to operate from the perspective of the history of human information dissemination (see Fig. 3), the primitive human society communicated through language (sound) and body movements. Later, with material civilization development, merely relying on voice or body communication

can no longer meet human communication needs, so words were created. As an abstract symbol, written language can only be grasped after learning. The reception of character information requires readers to transform the multiple symbol information they have learned in their minds to understand the content that writing language wants to convey.

However, people's lives are full of information in the information age. Simultaneously, people's pace of life and work has also accelerated. Therefore, it is a heavy burden for people to rely on words for communication. Therefore, to reduce the amount of information conversion, human beings have entered the era of picture reading. Image information is very intuitive for humans. People can understand without learning multiple written language symbols. Still, they need to be familiar and stored in the brain to understand specific symbols under social and cultural background and the meaning of symbols expressed by some specific images.

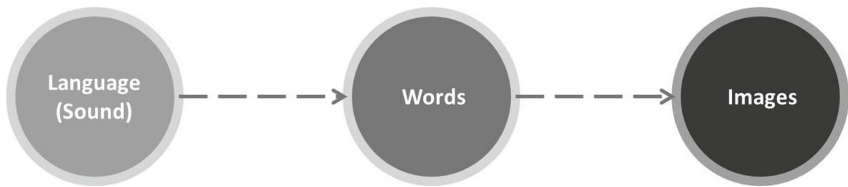


Fig. 3. The development history of information communication.

From the perspective of information processing psychology, users only need to send voice instructions through the most authentic way to complete voice interaction operation. While traditional speakers require users to extract the symbol information (text/image), they have learned to match the desired operation information (text/image) before pressing the operation key (see Fig. 4).

Therefore, compared with the traditional speaker operation way, the voice does not need brain conversion, significantly reducing the workload of information conversion for users. Therefore, voice interaction is a very “natural” operation mode for users.

3.2 Implicit Natural Interaction

The core of implicit natural interaction is to predict the behavior that users will or want to do. The focus is to perceive the situational information in the product's specific use process and then actively predict the demand according to the user's living habits, hobbies, use habits, etc.

Situational Awareness Theory

In 1994, Schilit et al. [17] put forward the concept of situational awareness for the first time. The core purpose of situational awareness is to actively perceive the changes of situational information around users and provide appropriate information and services at the right time according to the needs of current tasks. Situational awareness research mainly includes two points: one is to study people's perception, understanding, and feedback of the surrounding situation from the perspective of users, and the other is to

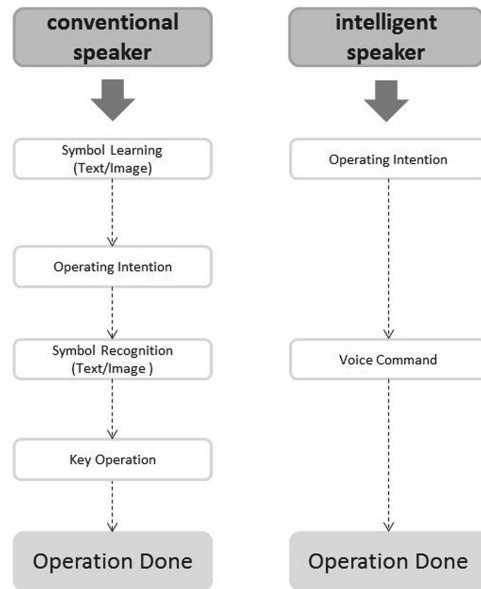


Fig. 4. Comparison of information conversion workload between traditional speakers and intelligent speakers.

study how to build a situational awareness system to perceive users and serve users by studying users' situational awareness principles.

Situational Factors Intelligent Product Design

In the design of intelligent products, the second point of situational awareness research is mainly applied. Intelligent products build their intelligent system by studying the user's perception of the surrounding situation when using the product and predicting users' potential unexpressed needs by perceiving the situational information.

The primary situational information that intelligent products need to perceive is summarized as environmental situation, user situation, and cultural situation (see Fig. 5). Among them, the perception of cultural context is advanced. The deeper the intelligent product system understands the cultural context, the more it can reflect intelligent products' development depth. Only by giving users the most appropriate feedback at the right time and on the right occasion can it provide users with a more excellent user experience.

The environmental situation is the natural environment information in the use situation, mainly including light environment, sound environment, temperature and humidity environment, and other information. Intelligent products perceive relevant information through various sensors, such as temperature and humidity sensors, photosensitive sensors, etc. These sensors are like human facial features, making intelligent products that have the sensory functions of seeing, listening, smelling, touching, and systematically recording the change of the surrounding environment information. Take the intelligent air purifier as an example to illustrate the influence of these factors on the design of intelligent products: when the air sensor in the air purifier detects the odor or smoke and



Fig. 5. Environment situation, user situation, the cultural situation in intelligent product design.

other polluting gases in the air, it will automatically turn on the purification mode, and the continuous detection of the sensor is more sensitive than people's sense of smell, so it can intelligently provide users with considerate user experience without people's active operation.

User situation is related to user characteristics, including users' habits of using the product, lifestyle, personal preferences, and other information. A corresponding user model can be built for each user based on user situational information collection. Through data analysis, intelligent products intelligently understand and learn from each user to provide a more considerate and personalized user experience. For example, a smart home housekeeper may need to manually set most of the actions in the early stage of use. It will learn your lifestyle and understand the scenes, times, and rules you set during this period. And then, after a particular time, it can intelligently manage your appliances. When you go out to work in the morning, the smart Housekeeper will help turn off all the appliances. Besides, when it's time to go home from work in summer, the smart Housekeeper has already turned on the air conditioner for you in advance, so you can enjoy the cool indoor space as soon as you go home.

Cultural situation is associated with the user's cultural background, including the comprehensive information of group culture, customs, values, etc. By understanding the cultural situation, intelligent products need to comprehensively judge the user's behavior or wants to do in this situation. People's behavior of making appropriate feedback through a comprehensive judgment of situational perception is regarded as "situational awareness." For example, when someone around you is answering the phone, you will pay attention to communicate with others in a low voice. The word "situational awareness" is used to describe people. Chinese people pay attention to the cultivation of situational awareness and think highly of etiquette. Japanese people pay attention to cultivating children's situational awareness when their children are very young and emphasize not to cause trouble to others. Civic education in Europe and the United States also reflects the emphasis on the cultivation of rules and occasion sense. Intelligent products need to perceive users in context and adapt to people's lives, so intelligent products should also have "situational awareness," which could contribute to a better user experience. For example, when the smart speaker is playing out at a high volume, suddenly someone nearby answers the phone. In this case, the smart speaker is expected to intelligently reduce the volume, not to affect others' telephone communication.

4 Intelligent Product Design Process Based on Natural Interaction

The core design direction of explicit natural interactions aims to design users' "natural" user mode. Hence, the essential point is that we need to observe users' "natural" behavior in their daily life to find more suitable interactive ways in line with the user's natural behavior and reduce the information conversion workload of the user to a greater extent. The core design of implicit natural interaction is to predict what the user is going to do or want to do, so we need to perceive the user and the surrounding situation, analyze the situation information, and then comprehensively judge and predict the user needs to determine the active interaction function of the product.

Based on the analysis of the characteristics of explicit natural interaction and implicit natural interaction in intelligent product design, the intelligent product's design steps based on natural interaction are proposed (see Fig. 6).

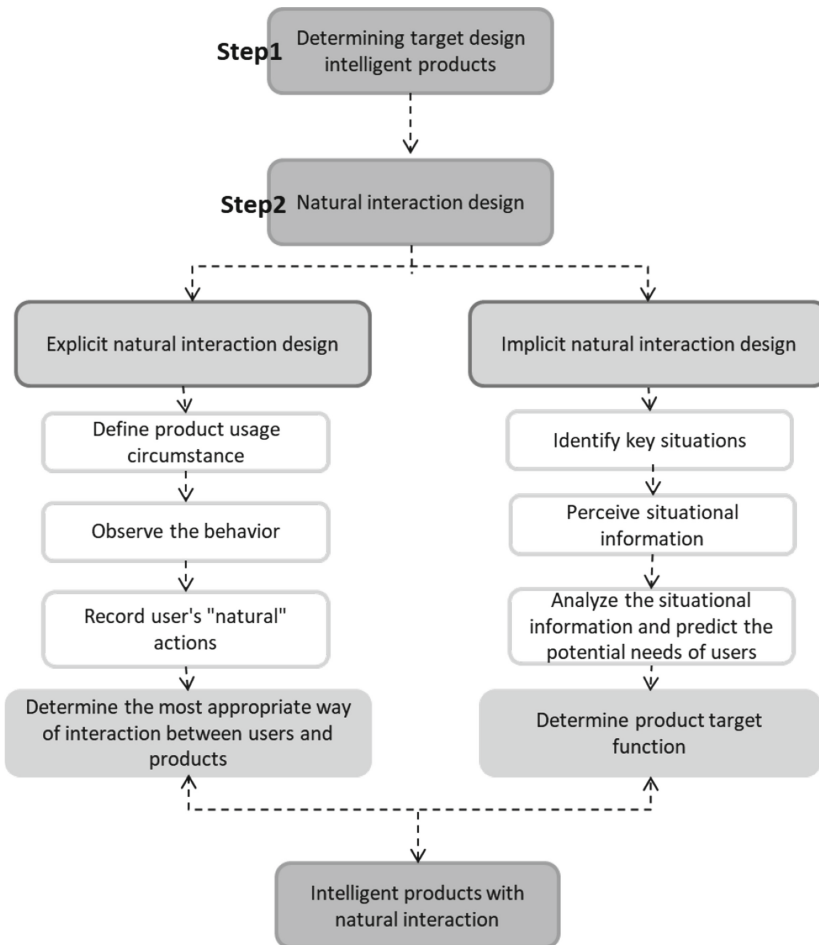


Fig. 6. Intelligent product design steps based on natural interaction.

4.1 Determining Target Design Intelligent Products

This step is a general starting step in product design. At the beginning of the design, specific design categories should be selected. Therefore, this step will not be explained in detail. This paper focuses on the design method of natural interaction function in intelligent products.

4.2 Natural Interaction Design

Explicit Natural Interaction Design - Behavior Observation

To determine the most appropriate and natural interaction mode, we need to start by observing users' "natural" behavior, including users' subconscious behavior, unconditional response behavior, and conditional response behavior.

Subconscious behavior is the tendency of people's unconscious behavior, which can be revealed naturally without any effort, and even can't be controlled and concealed subjectively. For example, some people's ears will turn red as soon as they communicate with others.

Unconditioned reaction behavior is reflex behavior, a kind of "natural" reaction behavior of human physiology without learning, such as knee jump reflex behavior.

Conditioned response behavior is a kind of matching reaction behavior left by accumulated learning or experience in our life. For example, if we set a song as a mobile phone ringtone for a long time, then we would think it's our mobile phone ringing when we hear this song in another place.

Therefore, it is necessary to observe the user's behavior habits in the specific product use circumstance in intelligent product design. And record the user's natural behavior to screen out the most natural interaction model that best matches the function of the intelligent product, which has the less information conversion workload of users naturally.

Implicit Natural Interaction Design - Situational Analysis

To determine the product's target functions, we first need to identify the critical use situation and then collect the situational factors related to the product's critical use situation. The primary situational information that intelligent products need to perceive is summarized as environmental context, user context, and cultural context. Among them, the perception of cultural context is high-level perception. The deeper the intelligent product system understands the cultural context, the more it can reflect intelligent product development depth.

Next, through comprehensive analysis and judgment, we can predict the behavior that the user will or wants to produce so as to give the user appropriate feedback in the appropriate situation and achieve the goal of according to the user's behavior to predict the user's next behavior and respond to the user's unexpressed demand in advance.

5 Case Study: Design an Intelligent Speaker

5.1 Determining Target Design Intelligent Products

As the voice control terminal of all kinds of intelligent products, intelligent speakers have a high degree of correlation with the user's life. Therefore, this paper takes the

optimization design of intelligent speakers as an example to verify the feasibility of the intelligent product design method based on natural interaction.

5.2 Natural Interaction Design

Explicit Natural Interaction Design

At present, voice interaction is a common and main operation mode of the intelligent speaker, which is also in line with the user's natural behavior. But the operation mode of voice interaction is not suitable for smart speakers' scenarios. For example, when the smart speaker is playing music, and someone in the user's home suddenly answers the phone, the user wants to pause the music, and in this case, the voice command is not the most appropriate way.

Therefore, in the above user situations, we found that the user needs to stop music. Then, through observing the user's subconscious behavior, we recorded that when people try to control the volume, there are two kinds of natural behaviors: one is that the subconscious reaction is to cover the vocal position; the other is to make the "Shh" gesture (see Fig. 7).

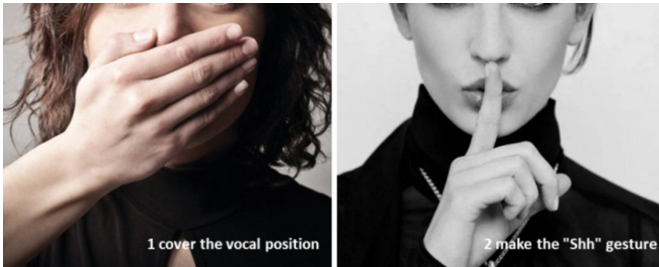


Fig. 7. Two kinds of natural behaviors when people try to control the volume: 1. cover the vocal position [18]; 2. make the "Shh" gesture [19].

Next, combined with the specific user scenarios and evaluating the difficulty of existing technology implementation, we finally decided that covering the vocal position with a hand is more appropriate and natural.

So in the end of the explicit natural interaction design part, it is concluded that to meet the need of users who want to pause music, except for the voice interaction, the auxiliary interaction way that needs to be added is that the user could cover the voice point of the intelligent speaker with his hand to make the music stop.

Implicit Natural Interaction Design

In this optimization example, the analysis and functional design are mainly focused on high-level perception, that is, cultural context.

Through interviews with smart speaker users, we screened out the critical situation: at night, users immerse themselves in music but unintentionally affect their neighbors' sleep. After a comprehensive analysis of the environmental situation factors - night time, user situation factors - preference for listening to music loud at night, cultural

situation factors - group culture, we determined that the active interaction function of the intelligent speaker is to set the maximum volume limit from 22:00 to 6:00, so as to avoid the possible negative impact of user behavior and provide a more humanized user experience.

After the above design steps, we get two optimization functions of an intelligent speaker based on natural interaction: one is that the user covers the speaker with his hand and the music is suspended; the other is a maximum volume limit of dB between 22:00 and 6:00.

5.3 Prototype Production

The prototype consists of hardware and software. The hardware includes the appearance modeling (see Fig. 8) and internal functional components. Bamboo board environmental-friendly materials are used for appearance modeling, and CNC machine tools are used to make model parts and assemble them. The internal functional components consist of an ultrasonic rangefinder, Bluetooth audio amplifier board, loudspeaker, etc. The software part uses Arduino IDE to program. Users can connect mobile phones and smart speakers through Bluetooth to play music. When the user covers the bell, the feedback distance of the ultrasonic rangefinder is less than 10, and the music is suspended.



Fig. 8. The product prototype.

5.4 Instructions for Natural Interactive Speakers

This intelligent speaker has the following functions: first, it can pause music more naturally. When someone in the user's home suddenly answers the phone or wants to pause the music, they can use the natural "natural" behavior - covering the voice with their hands (see Fig. 9). Second, the decibel limit function at night. When the user is immersed in music at night, the smart speaker will automatically turn on its "situational awareness" function, automatically help you adjust the maximum volume that can be played. To avoid the user's unintentional influence on neighbors' nights of sleep, promote harmony between neighbors (see Fig. 10).



Fig. 9. Stop the music by covering the vocal place with their hands.



Fig. 10. The smart speaker’s “situational awareness” [20].

6 Conclusions

The design of intelligent products based on natural interaction enhances the user experience, captures the user’s real needs, and implements the actual user-centered design. Based on the theories, the core of intelligent product design reduces the user’s information workload and predicts user behavior and the user needs. It is about situational awareness: to respond to the user’s needs, not expressed. The presented design case demonstrated a process that tries to enhance the smart speakers’ user experience, improve the design efficiency, and provide the user with a more personal and personalized experience.

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