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Research on the Integration of Industrial Design and Interaction Design under the Trend of IoT and Product Intelligence

Haiyang Yu, Keheng Zhao*, Jia Qin
Changzhou Institute of Technology, Changzhou, Jiangsu 213000, China
*Corresponding Author.

Abstract:

The age of the Internet of Everything is approaching, thanks to the rapid growth of contact technology such as 5G, and AI technologies is also growing swiftly and progressively being applied to numerous industrial items. It is anticipated that in the near future, a large number of products will share data processing and control functions with cloud computing devices via their own installation of computing chips or via the mobile Internet, and product design will gradually include more digital terminal interaction design. The rise of the Internet of Things (IoT) and product intelligence has made interface design a significant aspect of industrial product design, and the two are gradually integrating. Investigating the directions, modalities, and depth of interaction design in product design are essential subjects in the field of industrial design. Theoretical analysis and quantitative psychological research methods are used in this study. First, it examines the evolution of interaction design and its trends in relation to the Internet of Things and product intelligence, proposing an integrated development of interaction design and industrial product design, the approach and form are given from three perspectives: intelligence, control distance, and user group. Then, a novel "continuous psychological scale" is presented, and a matching psychological survey is constructed in design psychology using the user research approach to collect quantitative data on the relative value of interaction design in distinct types of integration. We acquired ratings expressing consumers' individual sensations through data analysis, and identified the degree of effect of each separate aspect on the relevance of the interaction component of the product design, as well as the contrasts and connections between them. The Internet of Everything and product intelligence have resulted in a profound convergence of product design and interface design. Different elements should be completely explored during the product design process to impact the relevance of interaction. The data gathered from the psychometric tests in this study may be utilized to assist interaction design work in many forms of product design in the design profession. The findings of this study provide important practical guidance for interaction design in product design; however, due to the time and conditions of the study, our classification of the factors that influence the importance of interaction may be insufficient, and further related research will be the focus of the next part of this project.

Keywords*: Internet of Things, Product intelligence, Industrial design, Interaction design, Design psychology, Psychological scale.*

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I. INTRODUCTION

The age of the Internet of Everything is approaching, thanks to the rapid growth of communication technology such as 5G, and AI technologies is also growing swiftly and progressively being applied to numerous industrial items [1-3]. It is anticipated that in the near future, a large number of products will share data processing and control functions with cloud computing devices via their own installation of computing chips or via the mobile Internet, and product design will gradually include more digital terminal interaction design [4]. The "human-machine interaction" of industrial products for the Internet of Everything and product intelligence will be integrated with the "human-computer interaction" of traditional computer fields, and there will be no clear boundaries between them, as is the inevitable trend of product design development. In product design, this is an unavoidable trend [5]. To meet the evolution of the times, investigating the directions, modalities, and depth of interaction design in product design are essential subjects in the field of industrial design.

In this study, we will discuss the trend of product-interaction design integration, provide specific forms of integration, and use the continuous psychological scale developed by our team to determine the importance of interaction design in these specific forms of integration via psychometric testing in accordance with the user research method in design psychology. It is intended that the findings of this study will serve as a model for future product design methods in the context of the IoT and product intelligence.

II. TRENDS IN THE INTEGRATION OF PRODUCT DESIGN AND INTERACTION DESIGN

2.1 The Emergence of Interaction Design

The phrase "interaction design" as a new design field may be traced back to industrial designer Bill Moggridge's 1984 presentation. The term "Soft-face" was then offered, and it was eventually changed to "Human-computer Interaction Design". Because the major objective of interaction design is the link between person and computer, conventional interaction design focuses on designing the operational interface of computer software [6]. Clearly, there is a distinction between "interaction" in interaction design and "interaction" in traditional ergonomics, and a study of the interaction design process can aid in understanding the unique link between the two.

During World War II, a research group at the University of Pennsylvania created the world's first computer, the ENIAC, to solve the problem of calculating large amounts of military data for the United States military. The ENIAC took up about 1,000 square feet of space and couldn't store information, so human-computer interaction relied on manual card insertion and light switching. Computers have advanced at an alarming rate since then. Initially, transistors replaced electronic tubes, and as microelectronics technology advanced, the components on processors and storage became smaller and more numerous. Computer computation speed and storage capacity were quickly increasing, and the way computers operated was changing. Prior to the advent of PCs and graphical user interfaces,

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computer-human interaction was still referred to as "human-computer interaction" in the classic ergonomics area. As PCs grew more popular, the general population, who were not computer specialists, wanted an easier and more comfortable method to use them without learning, and so the GUI was formed.

2.2 The Relationship between Interaction Design and Ergonomic Design

From the analysis of the emergence of the discipline of interaction design, we can see that, compared to traditional ergonomics, where the object of interaction with human beings is more focused on the physical part of man-made objects, the "interaction" in interaction design refers specifically to the interaction between human beings and computers. The essence of interaction design is to design the way and process for users to communicate with the computer through the software interface and use the computer to accomplish various tasks.

The design of the computer itself is an excellent example of collaboration and division of work between interface design and ergonomic design. For example, from an ergonomic standpoint, the first thing to consider is the size of the laptop, such as whether the size of the entire computer is easy to carry; whether the relationship between the screen flip angle and the user's line of sight and perspective during operation is reasonable; and whether the size of the keyboard and keys are in line with the size of most people's hands, among other things. Furthermore, the performance of the physical aspects of the action, such as the depth of the keyboard push, resistance, rebound speed, and so on, should be addressed. Interaction design is concerned with the mode of operation, procedure, and interface design of a computer operating system, various applications, websites, a keyboard, mouse, screen, and other devices. The integration is part of the overall product's human-machine design.

2.3 New Trends in Interaction Design

Aside from computers, the majority of conventional industrial items are controlled by physical components (such as knobs, levers, buttons, pedals, etc.). As a result of evaluating the link between ergonomic design and interaction design, we can assume that most conventional industrial product designs only feature ergonomic design and not interaction design. However, with the advancement of IoT and AI technologies, this position will drastically alter.

The Internet of Everything is one of the most important future product development trends. The IoT is a network that links all things to the Internet using information sensing devices and an agreed-upon protocol for information exchange and communication in order to accomplish intelligent identification, placement, tracking, monitoring, and management. Obviously, if you want an object to be network-connected, it must include components for broadcasting and receiving signals. When an item can receive various types of information, its functions can continue to develop in the direction of processing such information, and processing such information necessitates the use of hardware and software capable of storing and processing data. Von Neumann, the computer's father, devised the classical computer architecture, which included input, output, storage, and a central processor. The computer is made up of

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these structural and functional components. As a result, one of the most significant developments brought about by the development of the IoT for diverse industrial products is the incorporation of part or all of the components and functions of a computer in various forms.

Product intelligence is another key industrial product development direction. Intelligent products are those that, through different technologies, can partially replace human thinking, analysis, and judgment in function. Obviously, a really intelligent product must include input, output, and analysis features for varied data and information processing. The same result may be proven using Von Neumann's classical computer architecture. One of the most significant developments brought about by the development of product intelligence for diverse industrial products is the incorporation of part or all of the components and functions of a computer in various forms.

It can be seen that both the IoT and product intelligence are causing an increase in the number of items with computer functionalities (later will be unified called "computerization"). Such products' designs, in addition to the usual ergonomic design, clearly require improved interaction design components. This section concludes that the rise of the Internet of Everything and product intelligence has made interface design a significant aspect of industrial product design, and the two are gradually integrating.

III. THE SPECIFIC FORMS OF INTEGRATION BETWEEN PRODUCT DESIGN AND INTERACTION DESIGN

Despite the fact that the essence of both the IoT and the trend of product intelligence is computerization, they both contribute to the growing relevance of interface design as part of their design effort. However, there are variances in the precise types of integration across items in terms of interaction method, process, and usage. The following is an examination of the many affecting elements.

3.1 Interaction of Products with Different Degrees of Product Intelligence

Most products, such as sweepers that can detect garbage and charge automatically; air conditioners and humidifiers that can automatically set parameters such as temperature and humidity by detecting the environment; planters that can detect soil and air conditions and automatically water and fertilize; and health, physical therapy, and beauty equipment that can detect human body data and set functions based on it, can be developed in the direction of product intelligence. The more intelligent the product, the more natural and consistent with human instinctual behavior the technique of transmitting information to achieve the interactive function [7-9]. The human-machine interaction of products encompasses information flow from people to products and from products to people in both directions.

Control information is the information that people transfer to the product, and there are numerous ways to pass control information, which may be split into two categories: active control and passive control. Active control refers to a person's ability to control a product by active operation or behavior, such as the use of buttons, knobs, levers, pedals, and other manipulative devices. This form of conventional control

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does not often require product intelligence. However, as technology advances, active control techniques like touch screen, voice control, and gesture control become increasingly prevalent, necessitating the use of products with computerized data processing and analysis capabilities. Passive control implies that the product can detect diverse information about people via sensing devices, process and evaluate it to establish user demands, and then automatically adjust the product's operating parameters [10]. Obviously, this is the most common type of human-computer interaction in intelligent products.

Display information refers to the numerous information sent back to consumers by the product. There are several methods for transferring display information [11]. In general, any method that may elicit a variety of emotions can be applied [12]. At the moment, the most common are screens for visual display and speakers for auditory display, but head-mounted displays and 3D projection devices are becoming more sophisticated, and other devices that can evoke sensations such as skin, movement, and balance, such as simulated body wear devices and simulated motion devices, are also being developed [13]. Similarly to control information, the higher the degree of product intelligence, the more products that can automatically show matching information based on user needs evaluation.

3.2 Interaction of Products with Different Control Distances

IoT enables items to vary their information processing functions, either by putting a CPU at the product end or by computing directly from a cloud-based computer. This has little effect on user interaction behavior in usage. Another function of IoT, however, has a direct influence on the form of product and interaction design integration, and that is the control of the product at different distances. For example, most modern mid-range and higher family automobiles have integrated on-board computers and implement proximity control via a big center console screen and voice interface, among other things. Simultaneously, with the growing use of 5G technology, Telematics technology for long-distance control is fast evolving [14].

To enable proximity control, input and output components must be configured directly on the product and an interactive interface must be designed. Microwave ovens, electric ovens, and other home cooking gadgets, for example, include control panels that allow you to adjust various cooking conditions. It is not required to have input and output interfaces on the product entity to accomplish a particular distance control, and the associated interaction techniques will be different. There are more remote control devices for medium distance control, such as aerial drones, detecting robots, and so on. If the preceding example's cooking appliance allows consumers to book cooking time and other operations through mobile phone when they are not at home, it is the product that adds the interaction form of remote control.

3.3 Interaction of Products with Different User Groups

There will be many integration forms of product and interface design for intelligent items connected with the IoT, based on their individual user groups and usage scenarios. There are three types of use: personal, domestic, and public. Individuals, such as smart health wristbands, may detect and record health

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data, which can then be sent to the network for additional processing and analysis. Household devices, such as different household appliances that can be managed remotely via mobile phones, may perform operations such as setting, querying, reserving, and reminding. Cell phones may also be used to reserve public items such as courier lockers, milk ordering lockers, public laundry machines in apartment buildings, public printers in office buildings, capsule hotels at airports and trains, and item rental lockers. Users obviously have varied demands in terms of interacting with items from different user groups and usage scenarios.

Because of the complexity of their functional demands, the many divisions in the preceding analysis are not separated, and there are many products that have numerous forms of cohabitation in the form of integration of physical products and interactive portions. To serve patients, several hospitals, for example, deploy information service machines in the lobby (for public use) and registration systems on mobile phone applications (for personal or home use). Another example is smart refrigerators, which can detect the quantity or shelf life of food (very intelligent) and may be programmed in a variety of ways via a control panel (proximity to control information) and integrated with mobile phone applications to trigger food procurement information (distance to display information). Furthermore, children's companion robots with many interactive functions for children on the body entity (personal, proximity control, and moderate product intelligence), while parents may use the cell phone app for monitoring and setup (remote control)...

IV. PSYCHOLOGICAL MEASUREMENT OF THE INTEGRATION DEGREE

4.1 Psychological Survey Scheme Design

The many views discussed in the preceding study all have a significant influence on the interaction design component of product design [15]. We can better prioritize and allocate resources in the design process, and make reasonable trade-offs when we encounter problems such as conflicts between styling and interaction design, if we can clearly understand the degree of importance of the interaction component to the user (i.e., the degree of integration between product and interaction design) in the use of different types of products (which is a common problem in design work). The following Psychological survey scheme was created specifically for this purpose.

According to the user experience principle of design psychology, the integration degree of product design and interaction design is expressed psychologically by the importance degree that users can perceive in terms of the interaction function compared to the physical shape of the product. We intended to directly assess the user's intuitive experience perception in order to increase the accuracy of the findings, therefore we chose 30 product instances comprising various aspects that impact the interaction form stated in Part 3 of this study and prepared 30 test questions. The product descriptions were provided in the form of text with gray diagrams to eliminate the impact of individual product forms on the replies. Before answering each test question, the participant was given an explanation to verify that they understood the difference and link between the "form" and "interaction" components, and then they were asked to visually rate the significance of both on a "continuous psychological scale." The significance of the two

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components was then visually assessed using a "continuous mental scale."

4.2 Continuous Psychological Scale and Its Application

The continuous psychological scale is a novel scale that differs from the usual 5-point and 7-point scales. It is a psychometric instrument that we progressively developed and produced as part of our study, and it is mostly utilized on display devices such as mobile phone displays. Its key distinguishing feature is that it differs from the way psychological sensation values are answered in regular psychometric surveys. Traditional scale replies are dispersed; for example, on a 5-point scale, the answers are often "lowest, low, medium, high, highest." In our scale, the answers are displayed as a long bar on the screen with a slider that may be pulled from side to side, with just the ends of the bar and the center point noted. In this test, for example, if the participant believes that the two are equally important, he or she can move the slider to the middle of the entire line segment. If the participant thought the "interaction" was more significant, he or she may move the slider to the right, with the greater priority slider closer to the rightmost end. The test questions were integrated with a continuous psychological scale in this study, and the questionnaire was created to be shown on a mobile phone, as illustrated in Fig 1.

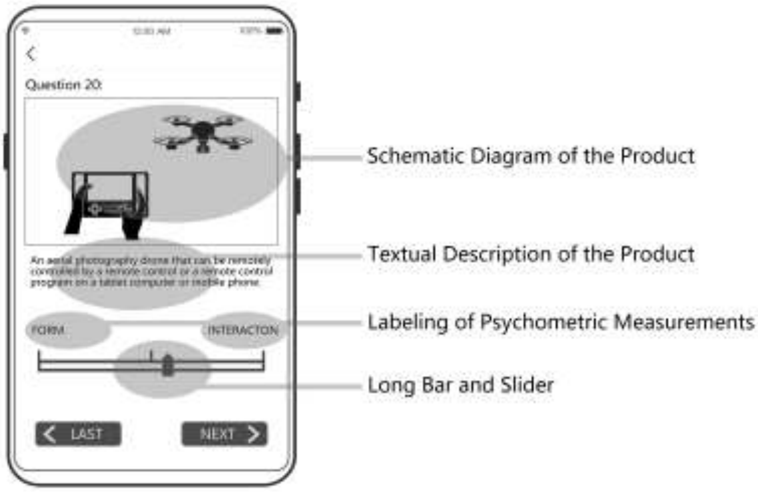

Fig 1: The questionnaire shown on a mobile phone

Because the purpose of the test, the specific meaning of the words labeled at the left and right ends of the long bar in the scale, and the operation of the slider are all explained in detail before answering the specific questions, the specific question page only contains the product schematic and a text description of the product features. Because 30 products were chosen for this exam, a subject may finish it by reading and comprehending the whole test purpose and function on the mobile phone, followed by answering the 30 test question pages. This allowed for the exam to be administered online more efficiently and with a larger test sample size.

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Other benefits of the continuous psychological scale are also obvious. Subjects may instantly drag the slider to the position that best reflects their sensations while answering questions on this scale, and their assessments are based on their most intuitive first feelings, bypassing the process of turning feelings into words and then making judgments on traditional scales. Furthermore, the test data is immediately obtained from the background program depending on the location of the slider in the long bar, eliminating the need to assign a value to the response on the usual scale. As a result, the scale has the benefit of being simpler to use, more direct in its assessments, and more accurate in its outcomes.

4.3 Survey Implementation and Data Processing

The survey was delivered using an online research platform using the test questionnaire we created, and 783 valid questionnaires were returned. The procedure yielded the following values in this test: when the slider was at the leftmost end, indicating that the subjects thought it was not important at all, the value was 0; when the slider was at the rightmost end, indicating that the subjects thought it was 100 percent important, the value was 100; and when the slider was in the middle position, the value was 50, indicating that the subjects thought the interaction was 50 percent important, indicating that the interaction was as important as the form. The remaining places' values and meanings were taken in the same way.

The resultant data was processed in accordance with the study's requirements. First, the test questions were written in such a way that the 30 products contained as many different types of factors that affect the degree of interaction integration as possible: low, medium, and high product intelligence; close, medium, and far control distances; and personal, household, and public use as different user groups and scenarios. Then, because the amount of the above 9 types is different in different products, we applied a combination of fuzzy hierarchical analysis and entropy weighting method to the questionnaire data to get a weighted value that accurately reflects the importance of each factor that affects the degree of interactive integration contained in these 30 products as much as possible. Finally, for each of the 9 forms, the final average of the weighted values of their combined ratings was taken as the final psychometric score, and the resulting values were taken to one decimal place, and the results are shown in Table I.

TABLE I. Numerical table of factors that affect the degree of interaction integration

<table>
<tr><th>3 factors</th><th>9 forms</th><th>Final psychometric score</th><th>Average score of each type of factor</th><th>Total average score</th></tr>
<tr><td rowspan="3">intelligence</td><td>low</td><td>52.6</td><td rowspan="3">47.9</td><td rowspan="9">58.8</td></tr>
<tr><td>medium</td><td>57.9</td></tr>
<tr><td>high</td><td>33.1</td></tr>
<tr><td rowspan="3">control distances</td><td>close</td><td>44.3</td><td rowspan="3">71.5</td></tr>
<tr><td>medium</td><td>78.6</td></tr>
<tr><td>far</td><td>91.5</td></tr>
<tr><td rowspan="3">user groups and scenarios</td><td>personal</td><td>37.2</td><td rowspan="3">56.9</td></tr>
<tr><td>household</td><td>48.5</td></tr>
<tr><td>public</td><td>85.0</td></tr>
</table>

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V. CONCLUSION AND ANALYSIS

Analyzing the data obtained in Table I, we can obtain the following research conclusions.

First of all, from the perspective of product intelligence degree alone, its impact on the importance of interaction is primarily reflected in the fact that the importance of interaction is greater than modeling in products with low to medium product intelligence, especially in products with medium product intelligence, which require specific user information and other settings, which are frequently relatively complex. Users also want to be able to use the procedure more effortlessly and conveniently. The significance of highly intelligent product interaction is significantly reduced, which should be explained by the possibility that users believe that this product has attained complete product intelligence, so they do not need to actively control it, and they have more energy to focus on the beauty of the product shape itself.

Then，from the perspective of control distance alone, the direct proximity control of items whose shape is substantially more relevant, but the relevance of interaction is no less vital. As a result, the distinction between the two is indistinguishable. And the medium distance remote control or more remote control products, obviously, interaction is more necessary since the user has fundamentally or simply cannot see the product entity.

Then， from the perspective of standpoint of the user group alone, the shape and design of personal use items are comparatively more essential. However, the necessity of interaction is not to be underestimated. For residential usage, the relevance of product shape and interaction is almost equal, with a little larger weight placed on shape. The relevance of form in public-use items is substantially lower. The cause for the discrepancy is similarly straightforward. Personal items are frequently more personal and intimate, necessitating a higher aesthetic value, whereas customers are less concerned with the style of public products, preferring straightforward application and easy operation.

Next, the three sorts of components are then horizontally compared. Users clearly believe that the interaction is more significant when examining the product's interaction function from the control distance component, which is produced by the high relevance score of interaction in both medium and long distance control. Interaction is also more significant when considering the user group, which is mostly due to the high value score of public products' interaction functions. The interaction importance of product intelligence is the lowest of the three categories of variables, but it is comparable to that of style.

Finally, the total average score of interaction importance across all criteria is 58.8, indicating that for IoT and intelligent products, interaction design, particularly design that considers the user's usage impact, is clearly more significant than mere product aesthetics. This validates the result of the theoretical analysis in Part 2 of this study with data once again.

In conclusion,, the IoT and product intelligence have resulted in a profound convergence of product design and interface design. Different elements should be completely explored during the product design process to impact the relevance of interaction. The data gathered from the psychometric tests in this study may be utilized to assist interaction design work in many forms of product design in the design profession. For remote controls and utility products, for example, the focus of design is on how easy it is for the user to use, and where there is a conflict between operation and modeling, the modeling should make suitable compromises. In contrast, for items that need a high level of intellect and personal usage, the aesthetics of the shape are equally crucial to the user when considering interaction concerns. When it comes to items with several sorts of qualities, a thorough study is necessary depending on the circumstance. The findings of this study provide important practical guidance for interaction design in product design; however, due to the time and conditions of the study, our classification of the factors that influence the importance of interaction may be insufficient, and further related research will be the focus of the next part of this project.

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