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Comparative Analysis of Scientometric-Based Interface Design Research

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ABSTRACT

In order to analyze the current situation and cutting-edge trends of interface design research in Chinese and international academia, as well as the respective research characteristics and paradigm differences between Chinese and foreign academia. VOSviewer and CiteSpace metrological visualization software were integrated to visualize and analyze the literature related to interface design research included in CNKI and Web of Science databases in terms of keyword co-occurrence, keyword clustering, keyword highlighting and highly cited literature by drawing knowledge maps. The results of the study show that the Chinese academic research on interface design focuses on the topics of graphical user interface, human-computer interaction, user experience, and usability, while the international academic research focuses on usability evaluation, intelligent user interface, adaptive user interface and augmented reality, etc. In terms of future research trends, the Chinese academic community focuses on user experience, eye tracking, visual design and other directions, while the international academic community starts to explore the direction of natural interaction from physical interaction, focusing on user experience, gesture recognition, natural user interface and other directions. In terms of research paradigms, the differences between Chinese and international academics are more significant, Chinese academics focus on qualitative research, while international academics focus on quantitative empirical research.

Keywords: Interface design, Knowledge map, Visual analysis, Bibliometrics, VOSviewer, Citespace

INTRODUCTION

The user interface (UI) is the medium through which the information between human and machine interacts (Lu 2008). Interface design generally refers to the overall design activity of the user interface in terms of human-machine interaction, operation logic, and interface aesthetics. Throughout the development of interface design, it has gone through three major stages: Command-Line Interface (CLI) - Graphic User Interface (GUI) - Natural User Interface (NUI). From Command-Line Interface to Natural User Interface, the interface design tends to be more and more humanized, naturalized and efficient, with more emphasis on user experience while pursuing operational efficiency (Luo et al. 2008). After more than half a century of development, interface design has gradually shifted from a single physical interaction form

to an unconscious interaction form that integrates both physical and virtual, and more and more scholars have started to conduct interface design research from user cognition, psychology and behavior (Guo et al. 2020; Yan et al. 2020); the field of interface design has also accumulated a large number of literature results. On the one hand, compared with the international academic community, Chinese interface design research started late, so it is necessary to further compare and summarize the research progress and current situation in China and abroad, and it is beneficial to further expand the connotation and extension of Chinese interface design research by learning from the advanced experience and methods of the international academic community and finding Chinese research characteristics at the same time. On the other hand, as an interdisciplinary field involving computer science, psychology, cognitive science, ergonomics, graphics and art design, interface design has a complex and diversified knowledge structure, and quantitative analysis of various literature with the help of scientific bibliometric methods can help to systematically explore the potential laws and information in the literature. Therefore, this paper compares and analyzes the current status of interface design research in Chinese and foreign academia by answering the following three questions through bibliometric analysis:

(1) What is the literature output of interface design research in Chinese and foreign academia and its research dynamics?
(2) Are there any differences in the focus of Chinese and foreign scholars in specific studies, and what are the research hotspots and research trends in Chinese and foreign academia?
(3) Are there any differences in the high impact literature and research paradigms between Chinese and foreign scholars in interface design research?

RESEARCH DESIGN

China National Knowledge Infrastructure (CNKI) and the international authoritative database Web of Science (WOS) were selected as the main literature data sources for the study of Chinese and foreign interface design. In terms of international research, the Web of Science core collection database was searched, the search term was set as “User Interface Design”, the search term field was restricted to “title”, and the literature search The search was conducted in the Web of Science core collection database, setting the search term as “User Interface Design”, the search term field limit as “title”, and setting the literature search type as “article” and “proceeding papers”, and the time dimension as 1992-2021, and a total of 1424 valid records were obtained. In terms of Chinese studies, in the CNKI search interface, set the subject as “interface design”, the document type as “academic journal”, and the year period as 1992-2021. In order to ensure the reliability of the data, the sources of journals in CNKI were limited to Peking University Core, EI, CSSCI, CSCD and SCI, and a total of 2682 relevant articles were retrieved. The data were screened and de-duplicated to eliminate irrelevant and duplicate literature, and to ensure that the data could cover the main results of interface

design research in China and the international academic community as far as possible.

In order to more comprehensively explore the characteristics and trends of Chinese and foreign interface design research, this paper adopts a combination of quantitative and qualitative research methods and uses the advantages of CiteSpace and VOSviewer literature visualization analysis tools (Wang et al. 2017), through keyword co-occurrence clustering, keyword high density Emergence, high-impact article analysis and other indicators comprehensively explore the knowledge structure and hotspot distribution of Chinese and foreign interface design research, and further compare the similarities and differences of Chinese and foreign academic interface design research hotspots, development trends, and research paradigms. CiteSpace, a knowledge graph visualization and analysis tool developed by Chaomei Chen's team, is widely used in bibliometric-related research (Chen 2006). VOSviewer, developed by Van Eck and Waltman, allows for the relational construction and visual analysis of bibliographic knowledge units (Vaneck and Waltman 2010).

VISUAL ANALYSIS OF INTERFACE DESIGN RESEARCH TEXT RESULTS

Analysis of Publication Trends in Research Literature

In order to grasp the temporal pattern and development trend of the literature output of interface design research in Chinese and international academia as a whole, we extracted the relevant literature from CNKI and WOS databases to obtain Figure 1. This shows that interface design research is a popular research direction in both Chinese and foreign academia. The literature output of interface design research in the period of 1992–2009 was relatively stable with a fast growth rate, and then began to decline from 2007 to 2012, and then began to rise again in 2013, reaching a peak in 2016 (97 articles/year) and then continued to decline. The trend line (R2 = 0.6229) constructed from

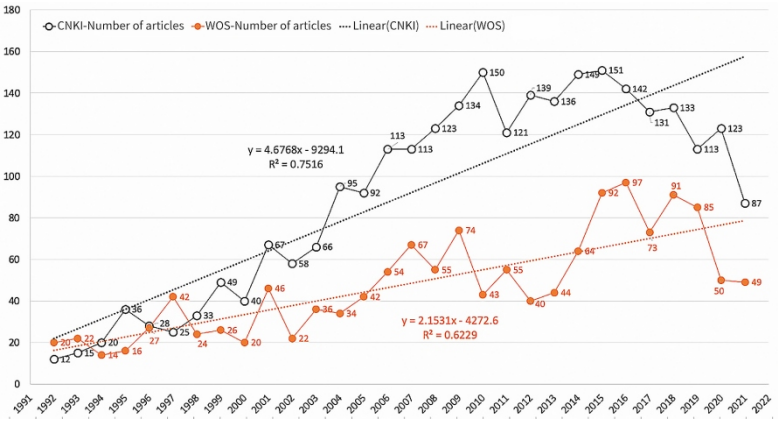


Figure 1: Statistical chart of the number of domestic and foreign interface design literature.

the WOS literature output data predicts that the literature output of interface design research will keep growing internationally in the future, but the magnitude is small; for Chinese research, the literature output grew steadily from 1992 to 2010, and the number of publications gradually stabilized from 2011, but the growth rate was relatively slow, and the overall output was relatively flat, and the trend started to rebound from 2013 to The overall output has been relatively flat, with a rebounding trend from 2013 to a peak in 2015 (151 articles/year), but a certain downward trend in the last two years. The total output of CNKI literature combined with the trend line shows that the increase in the number of literature output in China is relatively flat and may decline in the future.

Analysis of Research Hotspots and Cutting-Edge Trends

Research Hotspot Analysis

By running VOSviewer, we finally obtained the list of Chinese and foreign interface design research keywords (see Table 1) and the keyword clustering co-occurrence map (see Fig. 2 and Fig. 3). Among them, the keyword co-occurrence map of Chinese research has 113 nodes and 505 links; the keyword co-occurrence map of international research has 154 nodes and 2730 links.

From Table 1 and Figures 2 and 3, it can be seen that there are both similarities and differences between the research hotspots in the field of interface design in China and in the international academic community. In order to better grasp the characteristics and research differences between Chinese and

Table 1. Keyword frequency distribution of interface design research literature included in CNKI and WOS.

Rank	CNKI	Frequency	Web of science	Frequency
1	user interface design	437	user interface design	283
2	graphical user interface (Gui)	209	usability evaluation	113
3	human-computer interaction (Hci)	105	human-computer interaction (Hci)	83
4	interaction design	78	graphical user interface (Gui)	62
5	user experience	72	intelligent user interfaces	62
6	Database Design	66	system design	49
7	Software Design	66	user-centered design	47
8	system design	53	user experience	46
9	usability	52	design	35
10	touchscreen	42	information-systems	34
11	ergonomics	37	models	32
12	Visualization interface	36	performance	30
13	embedded system	35	augmented reality	25
14	Control System	33	interaction design	24
15	object-oriented	30	technology acceptance	24

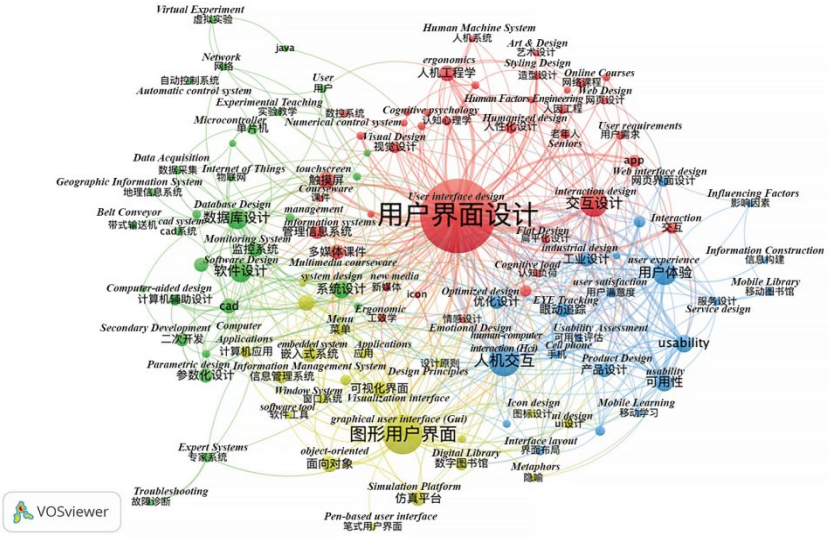


Figure 2: CNKI included interface design research keyword co-occurrence mapping.

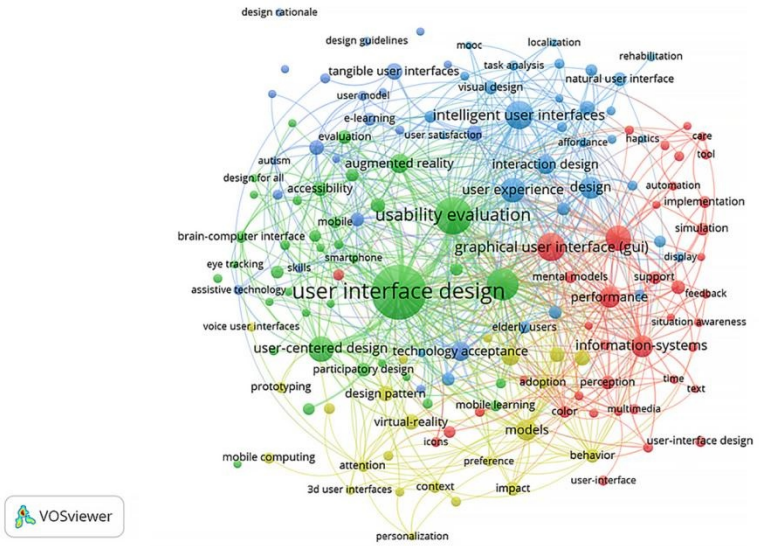


Figure 3: WOS included interface design research keyword co-occurrence mapping.

foreign interface design research, this paper will compare and analyze the research hotspots in China and international academia in terms of similarities and differences.

Similarities: First, Chinese and foreign academics are relatively consistent in research themes, and four main clusters have been formed in terms of keyword clustering, namely: #1 user research and interaction design, #2 graphic interface design, #3 computer-aided design, and #4 user experience and usability evaluation. Secondly, both Chinese and foreign interface design studies attach importance to usability testing and evaluation to ensure

that interface design solutions are easy for users to understand, learn, and use, and their common keywords are usability, human factors ergonomics, eye tracking, etc.; thirdly, both Chinese and foreign interface design studies attach importance to human-computer interface research to understand the operation logic relationship between human-computer interaction, and their correlation keywords include human-computer interaction, interaction interface design, and Fourth, both Chinese and foreign interface design studies attach importance to user research, emphasizing user-centered design in specific studies, reflecting a strong inclusive perspective, and their common keywords include user experience, humanized design, the elderly, user satisfaction, etc.; Fifth, both Chinese and foreign interface design studies attach importance to the use of graphical methods for computer user interface design, attaching importance to the visual perception-based graphical interface to improve the efficiency of users' visual target search, and their common keywords are graphical user interface, visualization, icon design, etc.

Heterogeneity: First, Chinese interface design research focuses more on the use of computer-aided technology for system development and design of interfaces, data analysis and graphic image processing. The key words include plc, matlab, computer-aided design, cad system, etc.; second, Chinese research focuses more on user interface and interaction design research in the field of industrial design, and the key words include industrial design, product design, styling design, etc.; third, Chinese interface design research is more traditional in interaction design, and is more inclined to the traditional and most simple and convenient physical human-computer interaction method of Third, Chinese interface design research is more traditional in terms of interaction design, and is more oriented toward the development and design of the simplest and most convenient physical human-computer interaction, with keywords such as touch screen.

From the perspective of international research: First, the international academic community has paid more attention to the exploration and research of cutting-edge and advanced natural interaction methods, and the interface design has started to develop from tangible graphical user interface to adaptive user interface, which has changed from emphasizing physical interaction to emphasizing natural interaction with the ability to adapt to users' information needs in order to enhance system stability. The key words include 3d user interface, natural user interface, brain- computer interface, adaptive user interface, etc. Secondly, the international academic community pays more attention to the combination of interface design and digital technology, emphasizing the restoration of interface digital information through virtual digital technology or enhancing the dynamism, realism and visualization of interface digital information, and at the same time, mobilizing the enthusiasm of user interaction and improving the effectiveness of user experience of human-computer interaction so as to promote the efficient dissemination of resource information. The key words include virtual reality, augmented reality, etc. Thirdly, the international academic community focuses on the intrinsic relationship between interface design and system data processing, and mainly discusses how to design more reasonable user interfaces through

reasonable system architecture and data model, with key words including System, Model, Interface, etc.

Analysis of Research Frontier Trends

In order to further study the respective frontier themes and development trends of interface design in Chinese and international academia, this section uses the VOSviewer keyword clustering index to statistically analyze the average occurrence time of keywords in WOS and CNKI literature respectively, and superimpose them on the original clustering graph to obtain Figure 4 and Figure 5. In order to ensure the rigor of the study, we used CiteSpace to determine the development trend of interface design research in China and abroad based on the frequency change of key co-cited papers combined with time-keyword clustering, as shown in Figure 6. Figure 6 shows the top 20 keywords in interface design research in China and abroad, and the darker part of the figure indicates the years in which the frequency of keywords cited in the papers is relatively prominent, reflecting the changing trend of research.

Combining Figure 4 and Figure 6, it can be seen that Chinese interface design research hotspots are divided into three obvious intervals. From the keyword evolution of the three intervals, the research content transitions from early user interface design to user experience, interaction design, and service design and presents a strong inclusive perspective, which is consistent with the results of the time-keyword clustering chart. A comprehensive analysis of the time-keyword clustering diagram and the high-density emergent words shows that the future research contents of Chinese academia focus on user experience, eye tracking, visual design, elderly, interaction design, service design, etc. The international research trends can also be roughly divided into 3 development intervals, as shown in Fig. 5 and Fig. 6, the keywords also present a strong inclusive perspective. In addition, topics such as

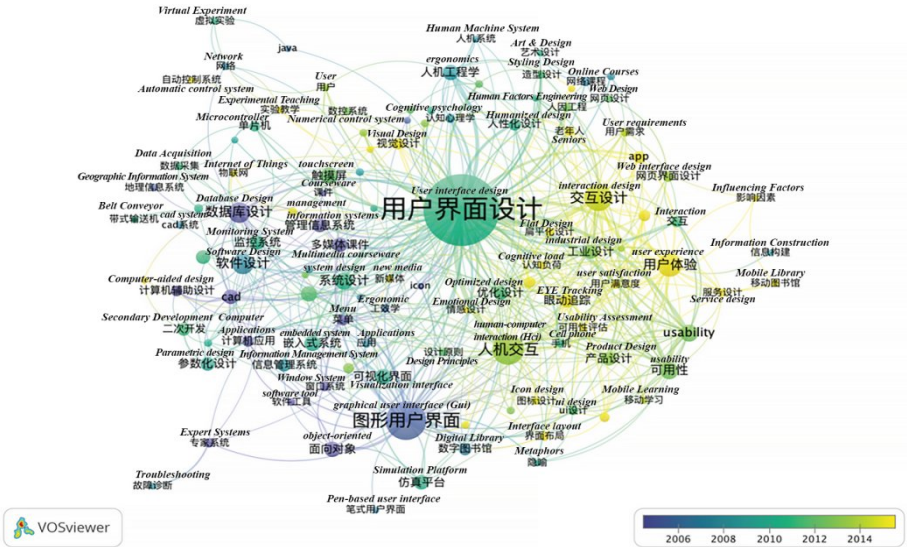


Figure 4: CNKI Data Keyword-Time Overlay Clustering Mapping.

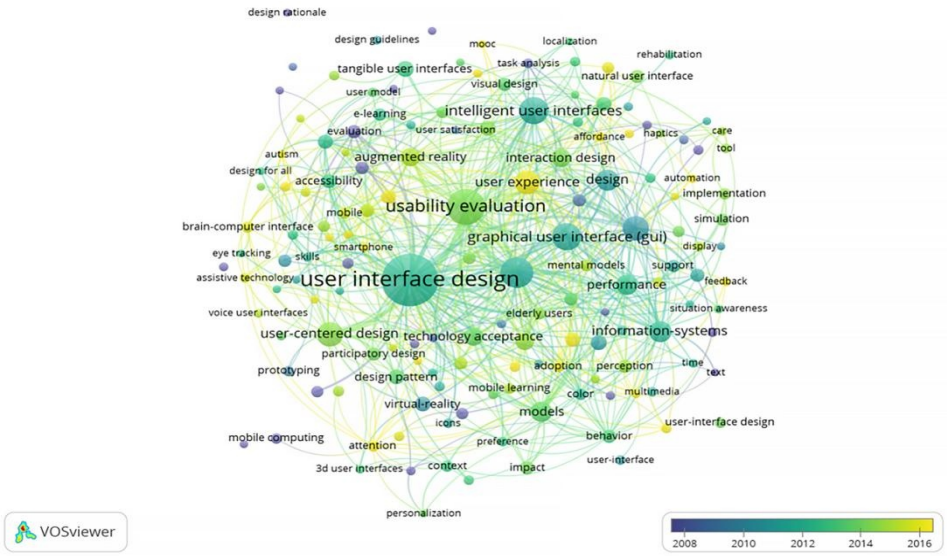
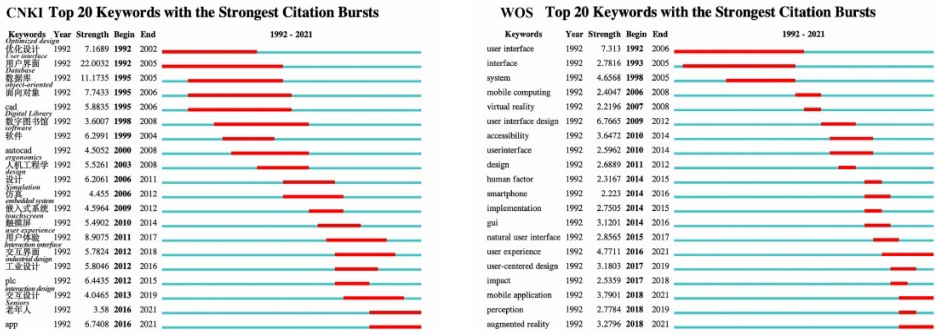


Figure 5: WOS Data Keyword-Time Overlay Clustering Mapping.



CNKI Top 20 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1992 - 2021
Optimized design 优化设计	1992	7.1689	1992	2002	
User interface 用户界面	1992	22.0032	1992	2005	
Database 数据库	1992	11.1735	1995	2005	
object-oriented 面向对象	1992	7.7433	1995	2006	
cad	1992	5.8835	1995	2006	
Digital Library 数字图书馆	1992	3.6007	1998	2008	
software 软件	1992	6.2991	1999	2004	
autocad	1992	4.5052	2000	2008	
ergonomics 人机工程学	1992	5.5261	2003	2008	
design 设计	1992	6.2061	2006	2011	
Simulation 仿真	1992	4.455	2006	2012	
embedded system 嵌入式系统	1992	4.5964	2009	2012	
touchscreen 触摸屏	1992	5.4902	2010	2014	
user experience 用户体验	1992	8.9075	2011	2017	
human-computer interface 交互界面	1992	5.7824	2012	2018	
Interface design 工业设计	1992	5.8046	2012	2016	
plc	1992	6.4435	2012	2015	
interaction design 交互设计	1992	4.0465	2013	2019	
Sensors 老年人	1992	3.58	2016	2021	
app	1992	6.7408	2016	2021	

WOS Top 20 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1992 - 2021
user interface	1992	7.313	1992	2006	
interface	1992	2.7816	1993	2005	
system	1992	4.6568	1998	2005	
mobile computing	1992	2.4047	2006	2008	
virtual reality	1992	2.2196	2007	2008	
user interface design	1992	6.7665	2009	2012	
accessibility	1992	3.6472	2010	2014	
userinterface	1992	2.5962	2010	2014	
design	1992	2.6889	2011	2012	
human factor	1992	2.3167	2014	2015	
smartphone	1992	2.223	2014	2016	
implementation	1992	2.7505	2014	2015	
gui	1992	3.1201	2014	2016	
natural user interface	1992	2.8565	2015	2017	
user experience	1992	4.7711	2016	2021	
user-centered design	1992	3.1803	2017	2019	
impact	1992	2.5359	2017	2018	
mobile application	1992	3.7901	2018	2021	
perception	1992	2.7784	2018	2019	
augmented reality	1992	3.2796	2018	2021	

Figure 6: CNKI & WOS data BURST keywords high density emergence.

eye-tracking, which is the frontier research direction in Chinese academia, is in the early stage of research in the international academia, which is also the difference between Chinese and foreign academia in the research frontier. Combining Figure 5 and Figure 6, the future research focus of the international community will be on user experience, feedback, gesture recognition, natural user interface, user- centered design, and decision making. The research content shows a shift from physical interaction to natural interaction, and the research topics are more cutting-edge than those in China, and the research perspectives also show strong diversity.

Analysis of High-Impact Literature

In order to better analyze and grasp the differences and similarities in research perspectives and research paradigms of interface design research in Chinese

and foreign academia, 15 high-impact classics were selected from each of the relevant literature within the search area, ranked according to the total number of citations, to further explore the characteristics and focus of each. In terms of research paradigms, the differences between Chinese and foreign interface design research are significant, which is consistent with the results presented by keyword clustering. The highly cited literature in Chinese academia mainly adopts qualitative research methods such as literature research method, case study method, and logical deduction method, while focusing on research in conjunction with design practice work. For example, Yang and Wang (2007), starting from the user's emotional experience, relied on the principles of perceptual engineering and combined with specific cases to provide an in-depth explanation of how to better design human-computer interaction interfaces; Tan et al. (2012), based on complex human-vehicle interaction situations, analyzed the design problems of multi-channel display and natural interaction modes in automotive human-computer interfaces for display and control, and verified the application through design cases; Pan (2008) reviewed the development process of human-computer interaction interface design, while analyzing new technologies and phenomena with case studies, and clarified that natural interaction interface design will definitely become a new hot spot in human-computer interaction interface design research; Si et al. (2015) proposed specific design specifications for interface design to better adapt the information presentation of mobile learning resources through literature review and case studies.

The highly cited literature of WOS is mainly based on empirical research methods, while focusing on a combination of literature analysis and case studies to investigate interface design in a qualitative and quantitative way. For example, Jaspers et al. (2004) conducted a related study by developing a cognitive task model of user interface input reflecting physicians' task behaviors, combined with an expert evaluation experiment of the model; Vincent Cho et al. (2009) proposed a theoretical model to assess the impact of perceived user interface design on the intention of continued use of self-paced e-learning tools and found that perceived usefulness and user satisfaction were two important predictors of continued use intention through user experiments; Medhi et al. (2011) to evaluate and improve the usability of user mobile interfaces through user experiments combined with case studies; Nielsen (1993), the "father of usability testing", discusses usability metrics in depth through four typical cases in user interface design, and emphasizes that the main purpose of usability evaluation in real-world projects is usability problem insight and specific strategies for interface design improvement; Najjar (1998) discussed the principles of educational multimedia user interface design through literature studies as well as case studies based on research findings in psychology, computer science, instructional design, and graphic design.

In general, in terms of research content, the highly cited literature in both Chinese and foreign academia focuses on multimedia user interface research. In terms of differences, the Chinese literature focuses on user experience, human-computer interaction, interface interaction methods, and multimedia, but also begins to explore the application implications of natural

interactive interfaces, while the international literature focuses on usability testing, interface design usability, ease of use, and user satisfaction. In terms of the differences in research paradigms, Chinese academics mainly focus on qualitative research methods such as literature research, case study analysis, and logical deduction, but such qualitative research methods have low reproducibility, difficulty in summarizing the deep-seated causes of problems, and are highly subjective in nature; while the international academic community mainly uses empirical research methods, through quantitative user experiments As well as the model research method to carry out research on interface design, and at the same time pay attention to the combination of qualitative and quantitative. Through comparison, it can be found that the combination of qualitative and quantitative research methods is showing great potential, which can effectively avoid the limitations brought by a single research paradigm, and the results of both can corroborate each other, which often leads to more comprehensive and reliable research conclusions, which also has certain significance for the follow-up research of interface design in Chinese and foreign academia.

CONCLUSION

There is still a lot of room for development of Chinese interface design research in the future. The development of interface design is constantly evolving, and in terms of research themes, attention can be paid to more cutting-edge technologies and research themes, such as: natural interaction interface, adaptive interface, multi-channel interaction, unconscious design, etc. Attention should be paid to the kernel needs of interface design from the cognitive and psychological needs of users, so as to provide some new ideas for the subsequent research of Chinese interface design, in order to promote the innovation and development of Chinese interface design. Interface design is a comprehensive embodiment of human-computer interaction, interaction logic and visual attributes, often a single discipline knowledge can not fully solve its design complexity, in the research paradigm, we can also pay more attention to interdisciplinary cross-fertilization, break the disciplinary barriers, broaden the research horizon, especially the synthesis of psychology, computer science, ergonomics, design and other disciplines knowledge base, while focusing on the combination of qualitative and quantitative research process, so as to continuously improve the level of Chinese and foreign interface design research.

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