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SURVEY ARTICLE



The Role of Service Robots in Restaurant Settings: A Meta-Analysis Study on Consumer Behavior and Intentions

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ABSTRACT

The employment of service robots in restaurants has become increasingly common. Previous studies have explored the factors related to the impact of service robots on consumers from multiple perspectives, but this topic still lacks an integrated empirical study to organize and analyze the conclusions of previous studies. This study obtained 46 empirical studies through the WoS and Scopus databases. Based on the conclusions and data of these studies and guided by the SOR theory, a holistic conceptual framework was constructed to describe how service robots affect restaurant consumers. This study tested the conceptual framework of the construct through meta-analysis and verified the moderating role of macro variables such as time and culture. This study not only has theoretical significance for future research but can also provide practical guidance for restaurant managers in the application and deployment of service robots.

KEYWORDS

Restaurant consumer; service robot; consumer intention; meta-analysis

1. Introduction

Among the many hospitality industries that have begun to deploy robot services, the restaurant industry is one of the industries where service robots are being popularized at a faster rate (Kao & Huang, 2023; Santiago et al., 2024). A survey report from Intellect Markets (2024) shows that the current market size of restaurant service robots is about \$1.29 billion, and the market size will be three times the current level by the end of 2030.

In recent years, researchers have conducted many studies on the topic of service robots in restaurants. Researchers have attempted to describe the impact of service robots on consumers from multiple perspectives (Kao & Huang, 2023; Song et al., 2022). However, the authors noted that although the number of studies related to this topic has been increasing and accumulating, limited researchers have been able to systematically summarize the existing results, especially based on the rich data in existing studies.

In addition, some studies have ignored the process of the antecedent variable affecting the outcome variable in the process of exploring the impact of service robots on restaurant consumers and have focused only on the direct relationship between the two variables. This neglect of the process, that is, the internal mechanism or mediating variable, in quantitative research can easily lead to unstable conclusions (Hayes, 2022).

There are still some controversial conclusions worth exploring in the existing research. As some studies have

pointed out, the capabilities of service robots have a negative impact on consumers' behavioral intentions (Balaji et al., 2024). The conclusions of other studies show that the capabilities of service robots have a significant positive impact on consumers' behavioral intentions (Guan et al., 2022). These different conclusions may be due to some macro variables, such as time and culture (Buhalis et al., 2023; Card & Little, 2016). However, individual studies are limited by various objective factors, and it is difficult to fully explore the moderating role of macro factors. In summary, the authors attempt to answer the following research questions through this study:

- RQ1.** What factors affect the impact of restaurants that employ service robots on consumers?
- RQ2.** What is the operating mechanism between these influencing factors?
- RQ3.** How do macro factors such as time and region regulate the operation of this mechanism?

Meta-analysis provides researchers with a feasible solution to the above questions. First, meta-analysis can reuse the rich data in existing studies to form a comprehensive model with a larger basic sample size, a wider range of adaptability, and a more stable overall structure (Blut & Wang, 2020; Card & Little, 2016; Ren & Lai, 2023). Second, meta-analysis can use the diverse samples in existing studies to break through the limitations of individual empirical research and explore the impact of culture and time on the

model on a larger scale (Blut & Wang, 2020; Ren & Lai, 2023).

Therefore, this study built an overall theoretical framework to describe the influencing factors based on the SOR theory and used a meta-analysis method.

2. Literature review and hypotheses

2.1. The SOR theory

The Stimulus-Organism-Response theoretical framework constructed by Mehrabian and Russell (1974) was proposed in the context of environmental psychology. This theoretical framework is used to explain how an organism's internal state and even behavioral response are affected by external factors (Mehrabian & Russell, 1974). This process consists of three stages: the first stage (stimulus stage) is receiving stimulation, the second stage (organism stage) is the internal processing of the stimulation information by the organism, and the third stage (response stage) is the psychological and behavioral response of the organism based on the stimulation and processing results (Mehrabian & Russell, 1974). The original SOR theory focuses on the stimulus factors in the environment in the first stage. However, some scholars have pointed out that in consumer-related research, the influencing factors in the first stage include both internal and external factors (Hochreiter et al., 2023).

Although the SOR theory has been widely used in research related to the impact of service robots on restaurant consumers, researchers often pay more attention to the stimulation of external factors. Some scholars have also noticed the importance of internal factors and added them to the model built based on the SOR theory to explore the phenomenon of the impact of service robots on consumers and obtain ideal results (Hlee et al., 2023). Therefore, this study will expand the factors of the stimulus stage to include both external and internal stimuli based on the original SOR theory.

2.2. Stimulus stage of consumers in restaurants with service robots

According to the SOR theory, in the process of an individual responding to a stimulus, being given a stimulus is not only a necessary condition but also the beginning of the entire response process (Mehrabian & Russell, 1974). Therefore, when exploring in-depth how individuals respond to the influence of stimulation in a specific context, researchers should first clarify the characteristics of the specific context and what stimulation exists in the environment. The specific context that this study focuses on is restaurants with service robots. Therefore, it is necessary to understand the characteristics of this type of restaurant and analyze the stimuli existing in this environment before conducting further exploration.

First of all, it needs to be pointed out that the most significant feature of this type of restaurant is that the consumers' interaction object is replaced by service robots instead

of human waiters. Service robots refer to robots that are based on automated systems and can interact with and provide services to customers (Wirtz et al., 2018). Service robots provide a series of benefits to restaurants, such as alleviating the pressure on human resources faced by restaurants, completing repetitive tasks with high quality and reducing costs (Huang et al., 2024; Wu et al., 2023). With the development of technology, service robots can already perform various positions in restaurants, so consumers will face more and more frequent interactions with service robots. The change in the attributes of service providers, that is, from human employees to service robots, will have a series of effects on consumers. According to the SOR theory, the attributes of this service provider are considered stimuli in the environment, which will not only affect consumers' processing of information but also affect consumers' psychological and behavioral responses (Hlee et al., 2023; Wu et al., 2023). The appearance and functions of service robots are the most concerning stimulus factors in previous studies (Molinillo et al., 2023; Santiago et al., 2024; Zhu, 2022).

Secondly, although these restaurants differ from traditional ones because they use robots to provide services, they are still essentially places that provide catering services to consumers. Many studies have pointed out that the restaurant environment, whether it is the physical or cultural environment, is an important factor affecting consumers (Guan et al., 2022; Gupta & Pande, 2023). Therefore, environmental factors other than service robots also play a role in the process of robots influencing consumers. For example, the opinions of peers and the servicescape of the restaurant are important factors affecting consumers' intentions to continue to use service robots in the future (Guan et al., 2022; Gupta & Pande, 2023).

Finally, in addition to the stimuli from the external environment described above, internal consumer factors should also be considered when applying SOR theory to explore consumer behavior (Hochreiter et al., 2023). In previous studies, the internal factors that have received the most attention were consumers' personal motivations for dining in restaurants. For example, consumers' identity needs and enjoyment needs play an important role in the process through which service robots influence consumers (Hwang et al., 2024; Jang & Lee, 2021).

In summary, in the stimulus stage, the factors that stimulate consumers can be divided into two categories: external environmental factors and internal factors. The external environmental factors comprise two elements: basic restaurant environmental factors and service robot characteristic factors. Since this study aims to explore the distinct impact of service robots in restaurants on consumers, these two elements of the external environmental factors will be discussed separately.

2.3. Organism stage of consumers in restaurants with service robots

According to SOR theory, perception is the first process in the organism stage (Mehrabian & Russell, 1974). The perception

process refers to the process of information input into the organism. This stage emphasizes the consumer's initial perception of stimuli. The main perception content explored in existing studies can be divided into two categories: the perception of benefit factors and the perception of cost factors. Among these, the perception of benefit factors is the primary focus of current research. Compared with cost perception, existing studies have paid more attention to consumers' benefit perception in restaurants with service robots, such as positive functional perception and need fulfillment perception (Song et al., 2022; Yang et al., 2024).

The second process in this stage is the cognitive process (Hochreiter et al., 2023). The cognitive process involves evaluating the current situation based on information, including both first-stage and second-stage perceived information. Cognitive evaluations include benefit and cost evaluation. It is worth noting that perception focuses on the initial reaction, with an emphasis on intuition and subjective judgment, whereas the cognitive process prioritizes the rational analysis of benefits, costs, and actual outcomes. For example, this includes the evaluation of service performance or the utility of the robot (Hamid et al., 2023; Huang et al., 2024).

The last process of the organism is the emotional process. According to the basic logic of SOR theory, the organism stage refers to the internal information processing, that is, the impact of stimulation on the individual (Mehrabian & Russell, 1974). Therefore, the emotional process, as a typical internal state of the organism, also belongs to the organism stage. Existing research has focused on the emotions of consumers in restaurants using service robots from comprehensive perspectives. Consumers dining in restaurants with service robots may experience pleasant, happy, fearful, and disappointed emotions (Huang et al., 2024). These emotions can be divided into positive and negative emotions.

2.4. Response stage of consumers in restaurants with service robots

The response stage is divided into two types in this study, namely explicit response and implicit response. According to the SOR theory, a response not only includes personal behavior but also attitude or behavioral intention (Mehrabian & Russell, 1974). An explicit response represents the result of consumers' behavioral reactions. This type of response actually manifests and has an immediate impact. For example, consumers' actual behavior in using service robots (Hamid et al., 2023).

Implicit response is another type of response in this stage, which represents the result of consumers' psychological reactions but excludes emotion. Although implicit response is also a psychological process, it is significantly different from the emotional process. According to the Theory of Planned Behavior, intention is the precursor of behavior and can be regarded as the preliminary expression of behavioral response, which exists between emotion and behavior (Ajzen, 1991). Therefore, intentions should belong to the response stage. Implicit responses receive the most attention in this

stage, especially consumers' usage intention and acceptance intention (Cha, 2020; Wang & Papastathopoulos, 2024).

2.5. Hypotheses

The various characteristics displayed by the service robot in the stimulus stage are one of the main sources of information for consumers' subsequent reactions to the robot. The characteristics exhibited by robots will affect consumers' perception of robots. For example, when service robots exhibit a higher level of anthropomorphism, consumers will have a more significant social interaction experience during use (Zhu & Chang, 2020).

The cognitive process is also directly affected by the characteristics of the robot, especially its functional characteristics. When robot functions are more complete, consumers' evaluation of benefits is greater and the evaluation of costs is lower (Barone et al., 2024; Belanche et al., 2021). The characteristics of the robot will also directly affect consumers' emotions in the organism stage and their intentions in the response stage. For example, the attractiveness shown in the appearance of a robot can directly stimulate consumers' positive emotions and word-of-mouth intention (Cha, 2020; Joo et al., 2023). Accordingly, this study proposes the following hypotheses:

H1a: The characteristics of service robots significantly affect restaurant consumers' perceptions.

H1b: The characteristics of service robots significantly affect restaurant consumers' cognition.

H1c: The characteristics of service robots significantly affect the emotional inclination of restaurant consumers.

H1d: The characteristics of service robots significantly affect the response of restaurant consumers.

According to the extended SOR theory in social science, an individual's internal factor is one of the important factors that can influence the organism and response stage (Hochreiter et al., 2023). Before coming into contact with service robots, consumers already have a certain information base and inherent characteristics. Individual characteristics and knowledge reserves are important factors that affect the subsequent stages (Hochreiter et al., 2023). This inherent information and the characteristics of consumers are considered internal factors in this study. Individuals' perceptions of service robots are directly affected by their internal factors. For example, consumers' demand for novel experiences will increase consumers' perceived ease of operation of service robots (Santiago et al., 2024). Internal factors will also affect consumers' evaluation of service robots. For example, the stronger the consumer's trust stance in technology before using the technological device, the higher the consumer's evaluation of its performance after using the device (Wang & Papastathopoulos, 2024). In addition, existing studies have pointed out that consumers' internal factors, such as escapist motivation, also have a direct impact on their emotions toward service robots (Chuah, Aw, et al., 2022). Previous studies have shown that internal factors can

transcend the organism stage and directly affect consumers' responses. Consumers' motivation, trust in service robots, and personality will enhance consumers' behavioral intentions (Chuah, Jitanugoon, et al., 2022; Gupta & Pande, 2023). Based on this, the following hypotheses are proposed:

H2a: The internal factors of restaurant consumers significantly affect their perceptions.

H2b: The internal factors of restaurant consumers significantly affect their cognition.

H2c: The internal factors of restaurant consumers significantly affect their emotional inclination.

H2d: The internal factors of restaurant consumers significantly affect their response.

The environmental factors in this study include the physical environment and the social environment. The environmental factors faced by consumers can affect their emotions and intentions. For example, the brand image created by a restaurant can arouse consumers' positive emotions (Kim et al., 2023). The opinions of groups around consumers toward service robots can affect consumers' intention to visit the restaurant and intention to use service robots (Choe et al., 2022; Gupta & Pande, 2023). Therefore, the following assumptions are made:

H3a: Environmental factors significantly affect consumers' emotional inclination.

H3b: Environmental factors significantly affect consumers' responses.

In the process of understanding, contacting and using service robots, consumers will receive the information generated in this process. This process is referred to as the perception process in this study. The information perceived by individuals can directly affect consumers' evaluation (Hassenzahl et al., 2015). For example, consumers' perceptions of beneficial information, such as their perceptions of ease of use and novelty, can affect their evaluations of benefits and costs associated with using service robots (Barone et al., 2024; Odekerken-Schröder et al., 2022). The perception of benefits or costs can also affect consumers' emotions and potential behavioral intentions. For example, the perception of cost can negatively impact consumers' positive emotions and their continued use intention (Seo & Lee, 2021; Steins et al., 2024). Therefore, the following hypotheses are proposed:

H4a: Restaurant consumers' perceptions significantly affect their cognition.

H4b: Restaurant consumers' perceptions significantly affect their emotional inclination.

H4c: Restaurant consumers' perceptions significantly affect their response.

Cognition belongs to the organism stage and represents the result of processing and evaluating internal and external information and perception (Hochreiter et al., 2023). In this study, cognition is divided into two categories: the evaluation of benefits and the evaluation of costs. Consumers' evaluation of benefits and costs will affect their emotions

and intentions. For example, when consumers believe that robots improve their user experience, both positive and negative emotions will be affected (Huang et al., 2024). Consumers' cognition of service robots will also affect their response to robots or restaurants that employ robots. When consumers give positive evaluations of robot performance, their willingness to use service robots, actual usage behavior and revisit intention will be promoted (Hamid et al., 2023; Molinillo et al., 2023; Odekerken-Schröder et al., 2022). Based on this, the following hypothesis is proposed:

H5a: Restaurant consumers' cognition significantly affects their emotional inclination.

H5b: Restaurant consumers' cognition significantly affects their response.

Consumers' emotional inclination refers to their emotional or attitude preferences toward service robots in this study. In technology-led service scenarios, emotions and attitudes are considered important factors in stimulating consumer intention. For example, Gursoy et al. (2019) found that in service scenarios dominated by AI devices, emotion is the key variable that affects consumers' acceptance intention and object intention. In restaurants with service robots, consumers' emotional inclination also affects their intentions. For example, consumers' positive attitudes and emotions increase their intention to use and pay more (Molinillo et al., 2023). Therefore, this study hypothesizes:

H6: The emotional inclination of restaurant consumers significantly affects consumers' responses.

Based on the above assumptions, the authors constructed the conceptual model of this study, as shown in Figure 1.

2.6. Macro-moderators

The empirical research articles obtained in this study were all cross-sectional studies. Many researchers have emphasized in their studies that consumers' perceptions of restaurant environments and devices may change over time (Barone et al., 2024; Molinillo et al., 2023; Pande & Gupta, 2023). Therefore, it was necessary to explore whether the hypothesized relationships established above were affected by time.

Some studies have pointed out the necessity of cross-cultural research because cultural differences lead to differences in individuals' perceptions and reactions to the same things (Z. Li et al., 2024). The meta-analytic method provides a suitable approach for cross-cultural research, so this study also sets culture as a moderating variable. Referring to previous research, this study selected five dimensions from Hofstede's dimensions of culture. In previous studies related to consumer behavior in the hospitality industry, individualism and uncertainty avoidance were the most common cultural dimensions used to verify culture and compare consumer behavior and perceptions (M. Li, 2014; Zou et al., 2022). These two cultural dimensions have been verified many times as having a significant moderating effect on

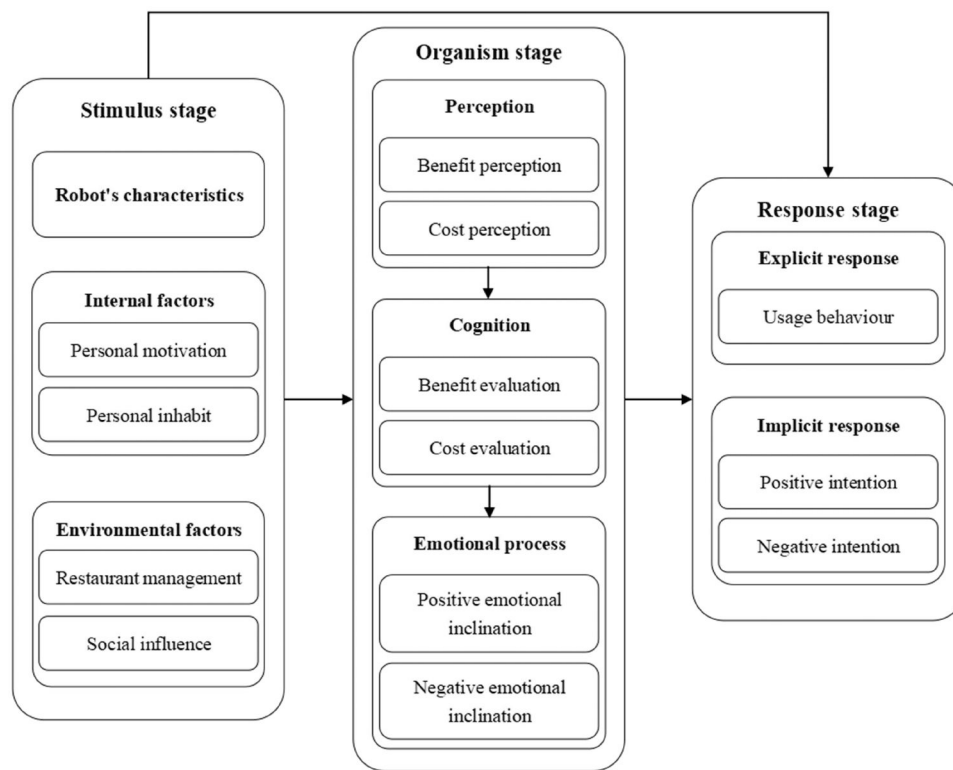


Figure 1. Conceptual framework. Note: Authors' work.

consumer behavior or perception (Daryanto & Song, 2021; Hansen et al., 2024).

In addition, considering that long-term orientation, power distance, and indulgence have been confirmed in previous studies to have an impact on consumer behavior in service scenarios where technological devices are applied (Chi et al., 2023; El-Manstrly et al., 2024), they were also selected as moderator variables for exploration. In summary, the cultural factors selected as moderator variables are individualism, uncertainty avoidance, long-term orientation, power distance, and indulgence.

3. Methodology

Based on the conclusions and data from previous empirical studies, this study used step-by-step coding and meta-analysis to organize and analyze the data. The meta-analysis method has the advantages of integrating previous data and exploring the moderating effect of macro variables (Afshardoost & Eshaghi, 2020; Buhalis et al., 2023). The literature used in this study was from English journal articles retrieved from the Web of Science and Scopus databases, with no restrictions on the publication time. The initial literature search was completed on June 20, 2024. The retrieved articles were strictly screened according to the following criteria: first, empirical research related to the impact of restaurant robots on consumers; second, the study needed to provide effect size or other data that could be converted into effect size. Specifically, this study obtained 148 nonduplicate articles from the two databases. After screening, 46 articles were finally included in the data set (see online Appendix), involving 50 independent studies, with a total sample size of 19,015 people

and 332 pairs of variables. The specific literature search and screening process is shown in Figure 2.

3.1. Recording and coding

Since the articles included in this study were all empirical research articles, there were already relatively mature names for latent constructs in these articles. However, it is worth noting that although some latent constructs had different names, they could be found to have the same essence as the observed variables. For example, "perceived advantages," "perceived usefulness," and "service performance" had different names, but their essence and meaning were consistent (Choe et al., 2022; Chuah, Aw, et al., 2022; Hamid et al., 2023). In reference to previous meta-analysis studies, this study classified and coded the constructs according to their essence and definition before conducting a formal meta-analysis (Fan et al., 2022). This coding process aimed to provide a consistent construction framework for subsequent quantitative meta-analysis so that the constructs from different studies could maintain consistency and comparability when conducting statistical analysis. At the same time, the coding process referred to previous studies and chose a theory as a guiding framework (Ladeira et al., 2023). Specifically, this study used SOR theory as the guiding framework and hierarchically coded the latent constructs obtained according to their connotations in the three stages of SOR theory.

Three researchers participated in the coding process. Two researchers read and recorded the information and data from the 50 independent studies. If a study contains multiple independent studies and these independent studies differ in terms of scenarios, samples, and variables, then

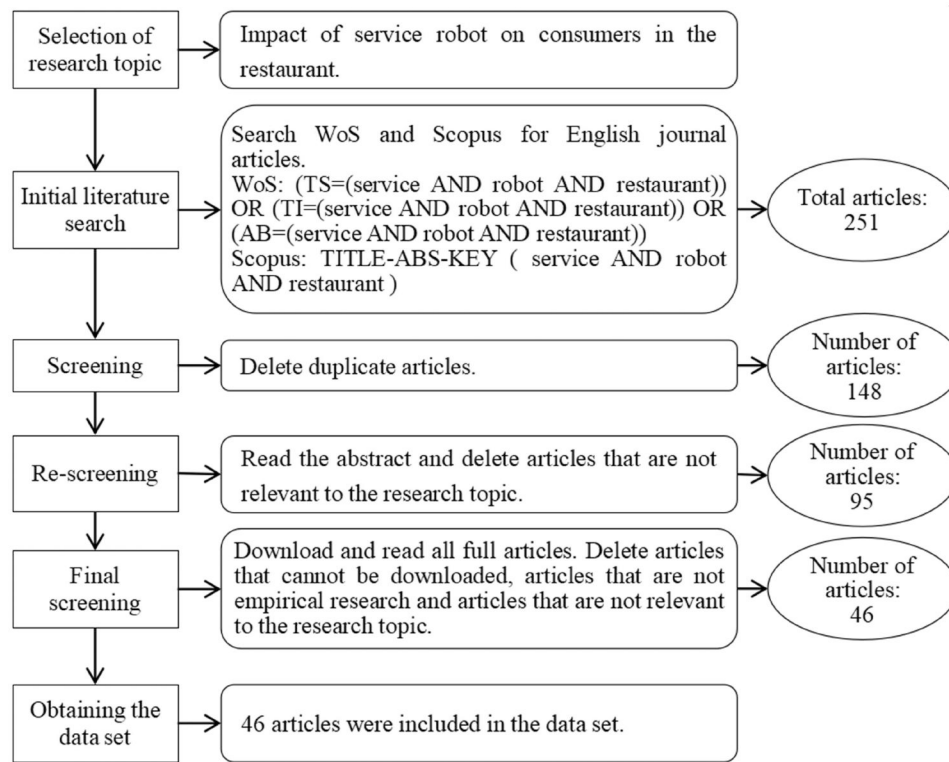


Figure 2. Literature selection process. Note: Authors' work.

these studies are recorded separately (Afshardoost & Eshaghi, 2020; Buhalis et al., 2023). The recorded content was checked by the third researcher to determine whether the recorded results were consistent and to ensure the accuracy of the data recording. The two researchers who recorded the information then hierarchically coded the identified variables according to the specific items of the variables and the definitions of the variables. After each round of coding, the two researchers checked the coding results and discussed the controversial results. For coding results for which a consensus could not be reached, the third researcher was invited to discuss. The final decision would be made after discussion.

3.2. Data processing

This study selected Comprehensive Meta Analysis V3 for data analysis. The recorded data were uniformly converted to Pearson r effect sizes before being imported into CMA V3. (Card & Little, 2016; Ren & Lai, 2023). All Pearson r effect sizes were converted into Fisher's Z in the software (Borenstein, 2009). Subsequently, this study conducted robustness and publication bias tests to ensure that there were no extreme values or publication bias (Ren & Lai, 2023). The random-effects model was used to test the significance of the r -weighted values and coefficients between each construct. The random-effects model is more inclusive of potential errors between different studies and can also reduce the impact of underestimation of standard errors (Ren & Lai, 2023).

As there were differences between different studies, such as differences in sample characteristics and sample collection time, this study further carried out the heterogeneity test.

Table 1. Coding results.

Constructs		Frequency
Stimulus stage (S)		
Robot characteristics (RC)		54
Internal factors	Personal inhibition (PI)	4
	Personal motivation (PM)	71
	Personality (PER)	3
	Restaurant management (RM)	3
Environmental factors		3
Organism stage (O)		
Organism-perception		
Benefit perception (BP)		84
Cost perception (CP)		5
Organism-cognition		
Benefit evaluation (BE)		121
Cost evaluation (CE)		21
Organism-emotional inclination		
Positive emotional inclination (PEI)		165
Negative emotional inclination (NEI)		7
Response stage (R)		
Explicit response		
Usage behavior (UBE)		2
Implicit response	Positive intention (PIN)	119
	Negative intention (NIN)	2

Note: Authors' work.

Conducting a heterogeneity test was an effective way to explore which of these differences were potential moderator variables (Blut & Wang, 2020). Finally, researchers tested the moderating effects of paths with significant heterogeneity.

4. Results

4.1. Coding results

The coding results and frequencies of the constructs are shown in Table 1. In the stimulus stage, the researchers identified three types of factors. The first type is related to

the characteristics of the robot, the second type is related to consumers, and the third type is related to the restaurant environment and social environment. According to Table 1, the frequency of factors related to consumers' motivation in previous studies is 71 times. The occurrence frequency of factors related to the social environment, restaurant environment and consumer personality in previous studies is the lowest.

The organism stage is the stage in which consumers process and handle information (Mehrabian & Russell, 1974). Hochreiter et al. (2023) further note that this stage is not only the stage where information is perceived and processed by the individual but also the stage where individuals' emotions and attitudes are activated. Based on the views of the above scholars, researchers identified three types of factors in the coding process. The first type is factors related to perception. The stimulus information from the first stage needs to be perceived by the individual. This information conversion process is named perception in this study. The second process in the organism stage is the cognition process. During this process, individuals evaluate the possible impact of the service robot on themselves based on obtained information. The third process is emotional inclination. The emotional inclination process includes consumers' attitudes and emotions toward service robots. Table 1 shows that the frequency of constructs representing positive factors is much greater than that of negative constructs at the same level. For example, the frequency of factors related to positive emotional inclination in emotional inclination is 165, which is more than 20 times the frequency of factors related to negative emotional inclination.

The researchers identified two types of response-related factors. The first type is explicit responses, and the second type is implicit responses. The results in Table 1 show that previous studies paid insufficient attention to negative factors. In addition, in the category related to explicit response, no factors related to negative explicit response were identified.

4.2. Publication bias and heterogeneity test results

The results of the funnel plot (Figure 3), the Fail-safe N value and Egger's two-tailed regression analysis show that there is no significant publication bias in the data included in this study. The I^2 values of the paths included in the test were greater than 78%, and the p value corresponding to the Q-value was less than 0.05, so there was significant heterogeneity (Borenstein, 2009; Card & Little, 2016; Ren & Lai, 2023). Therefore, it was necessary to test the moderator variables.

4.3. Hypothesis test

This study used the random-effect model to test the main effects of each path, and the results are shown in Table 2. Stimulus stage factors related to robot characteristics had a significant impact on consumer perceptions. Robot characteristics had a significant impact on consumers' perception, evaluation and positive emotional inclination ($r\text{-weighted}_{S\text{-}RC \rightarrow O\text{-}BP = 0.484$, $r\text{-weighted}_{S\text{-}RC \rightarrow O\text{-}BE = 0.432$, $r\text{-weighted}_{S\text{-}RC \rightarrow O\text{-}CE = -0.144$, $r\text{-weighted}_{S\text{-}RC \rightarrow O\text{-}PEI = 0.318$). However, consumers' positive intentions were not significantly affected by robot characteristics. Therefore H1a, H1b, and H1c were supported, and H1d was not supported.

The internal factors related to consumer personal motivation had a significant impact on benefit perception, benefit evaluation, positive emotional inclination, positive intention and cost evaluation ($r\text{-weighted}_{S\text{-}PM \rightarrow O\text{-}BP = -0.718$, $r\text{-weighted}_{S\text{-}PM \rightarrow O\text{-}BE = 0.556$, $r\text{-weighted}_{S\text{-}PM \rightarrow O\text{-}PEI = 0.529$, $r\text{-weighted}_{S\text{-}PM \rightarrow R\text{-}PIN = -0.373$, $r\text{-weighted}_{S\text{-}PM \rightarrow O\text{-}CE = -0.098$). The impact of personal inhibition on positive emotional inclination and positive intention was not significant. Consumer's personality among the internal factors had a significant impact on the positive emotional inclination and the positive intention ($r\text{-weighted}_{S\text{-}PER \rightarrow O\text{-}PEI = 0.123$, $r\text{-weighted}_{S\text{-}PER \rightarrow R\text{-}PIN = 0.411$). Therefore, H2a and H2b were supported, and H2c and H2d were partially supported.

Among environmental factors, both restaurant management and social influence had a significant impact on the positive emotional inclination ($r\text{-weighted}_{S\text{-}RM \rightarrow O\text{-}PEI = 0.742$, $r\text{-weighted}_{S\text{-}SI \rightarrow O\text{-}PEI = 0.553$). Social influence also had a significant impact on positive intention ($r\text{-weighted}_{S\text{-}SI \rightarrow R\text{-}PIN = 0.531$). Therefore, both H3a and H3b were supported.

Benefit perception in the organism stage had a significant impact both evaluation, emotional inclination and positive intentions ($r\text{-weighted}_{O\text{-}BP \rightarrow O\text{-}BE = 0.526$, $r\text{-weighted}_{O\text{-}BP \rightarrow O\text{-}PEI = 0.556$, $r\text{-weighted}_{O\text{-}BP \rightarrow O\text{-}CE = -0.179$, $r\text{-weighted}_{O\text{-}BP \rightarrow O\text{-}NEI = -0.192$, $r\text{-weighted}_{O\text{-}BP \rightarrow R\text{-}PIN = 0.409$). Benefit perception had no significant impact on negative intentions. Cost perception had a significant impact on benefit evaluation, positive emotional inclination and intentions ($r\text{-weighted}_{O\text{-}CP \rightarrow O\text{-}BE = -0.264$, $r\text{-weighted}_{O\text{-}CP \rightarrow O\text{-}PEI = -0.499$, $r\text{-weighted}_{O\text{-}CP \rightarrow R\text{-}PIN = 0.211$, $r\text{-weighted}_{O\text{-}CP \rightarrow R\text{-}NIN = -0.117$). In summary, H4a and H4b were supported, and H4c was partially supported.

Benefit evaluation in the cognitive process had a significant impact on emotional inclination, actual usage behavior and positive intention ($r\text{-weighted}_{O\text{-}BE \rightarrow O\text{-}PEI = 0.525$, $r\text{-weighted}_{O\text{-}BE \rightarrow O\text{-}NEI = -0.371$, $r\text{-weighted}_{O\text{-}BE \rightarrow R\text{-}UBE = 0.132$, $r\text{-weighted}_{O\text{-}BE \rightarrow R\text{-}PIN = 0.639$). Cost evaluation had a significant impact on positive emotional inclination and positive intention ($r\text{-weighted}_{O\text{-}CE \rightarrow O\text{-}PEI = -0.303$, $r\text{-weighted}_{O\text{-}CE \rightarrow R\text{-}PIN = -0.168$). Therefore, both H5a and H5b were supported.

Positive emotional inclination in the emotional process of the organism stage had a significant positive impact on usage behavior and positive intention ($r\text{-weighted}_{O\text{-}PEI \rightarrow R\text{-}UBE = 0.144$, $r\text{-weighted}_{O\text{-}PEI \rightarrow R\text{-}PIN = 0.763$). Negative emotional inclination had a significant negative impact on positive intention ($r\text{-weighted}_{O\text{-}NEI \rightarrow R\text{-}PIN = -0.176$). Therefore, H6 was supported.

Positive emotional inclination in the emotional process of the organism stage had a significant positive impact on usage behavior and positive intention ($r\text{-weighted}_{O\text{-}PEI \rightarrow R\text{-}UBE = 0.144$, $r\text{-weighted}_{O\text{-}PEI \rightarrow R\text{-}PIN = 0.763$). Negative emotional inclination had a significant negative impact on positive intention ($r\text{-weighted}_{O\text{-}NEI \rightarrow R\text{-}PIN = -0.176$). Therefore, H6 was supported.

4.4. Moderate effect test

This study tested the moderating effects of the percentage of females, education level (proportion of university and above), marital status (proportion of married), sample

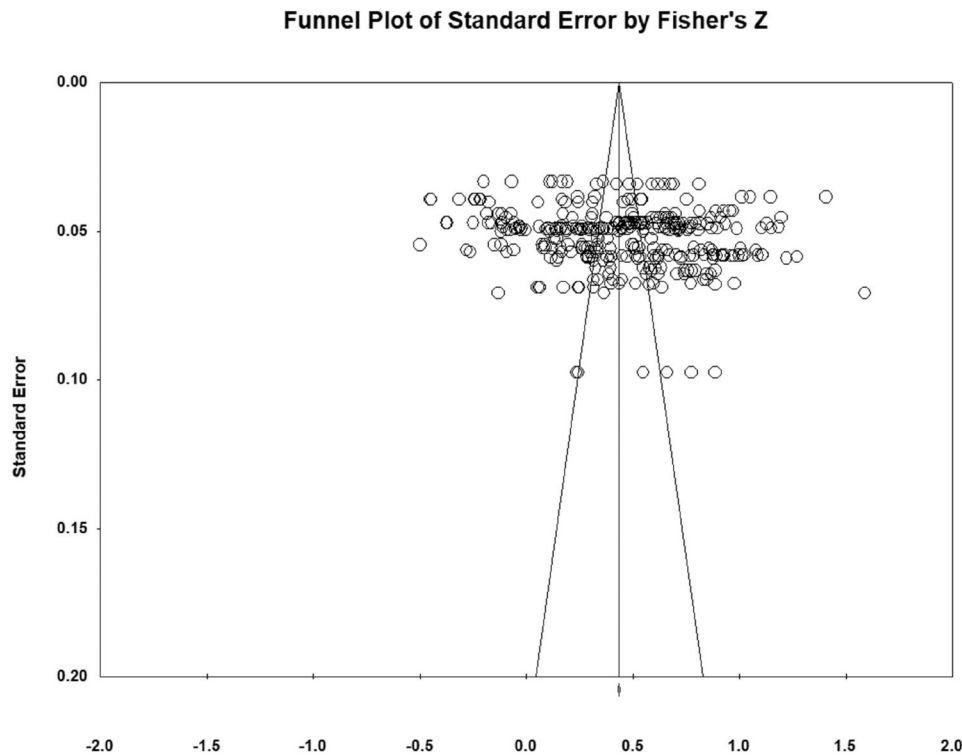


Figure 3. The funnel plot. Note: Authors' work.

collection time and five Hostede's culture dimensions. The test results show that the selected regulating variables all had significant moderating effects, but most of them had weak effect sizes. The researchers sorted out the paths with significant moderating effects, and the results are shown in Table 3.

5. Conclusion and implications

5.1. Conclusions

This study sorted out the internal operating mechanism of the factors in the organism stage through coding and analysis. The factors in the organism stage interact with one another sequentially, following the order of perception, cognition, and emotional inclination. Therefore, the general operating mechanism of the service robot's impact on consumers can be described as follows. Consumers raise internal perceptions of service robots under the stimulation of internal information (personal motivation and social influence) and external information (service robot characteristics and environmental factors). This is the main process for consumers to enter the organism stage from the stimulus stage. Subsequently, consumers evaluate and judge their gains and losses based on information and perception, and the evaluation results further affect consumers' emotional inclinations. Finally, consumers make intentional responses or actual behavioral responses based on their emotional inclinations.

In addition, some factors can also leapfrog this general influence process. For example, the characteristics of the service robot from the stimulus stage, the restaurant environmental and social environmental factors, and the internal

factors of consumers can have an impact on the response stage directly. Although the factors in the organism stage have a certain internal operation order, these factors can also skip the normal order and directly affect consumers' responses. For example, consumers' perception of beneficial information related to service robots can enhance consumers' positive intentions (Hamid et al., 2023; Joo et al., 2023). In addition, the results show that the perception of beneficial information cannot alleviate consumers' negative intentions. The perception of costs is an important factor that prompts consumers to have negative intentions. The above research conclusions provide specific explanations for the first and second research questions raised by the authors.

To answer the third research question, this study analyzed the moderating effects of some macro moderators. The analysis results show that the macro moderators selected in this study indeed play a significant moderating role, but the moderate effects of these moderators were small or even weak. According to the intensity classification of effect sizes by Cohen (1992), the intensity of effect sizes of most moderators in this study was weak. The weighted effect sizes were even smaller than the boundary value of 0.1 for small effect sizes noted by Cohen (1992). Among these moderators, the collection time had the strongest moderating effect. The effect size of collection time on the path "S-PM $\rightarrow$ O-PEI" was 0.1947. Although it exceeded the boundary value of a small effect size, it was still lower than the medium intensity level. The weighted effect size of collection time on the path "O-BP $\rightarrow$ O-BE" reached -0.3199 , and its absolute value exceeded the medium effect size level (0.3).

In addition, this study revealed that not all paths with significant heterogeneity were affected by the moderating

Table 2. Main effect results.

Hypothesis	Path	Effect size		Result
		k	r-weighted	
H1a	S-RC → O-BP	6	0.484***	Supported
	S-RC → O-CP	1	-0.148**	
H1b	S-RC → O-BE	25	0.432***	Supported
	S-RC → O-CE	2	-0.144*	
H1c	S-RC → O-PEI	16	0.318***	Supported
H1d	S-RC → R-PIN	4	0.196 ^{n.s.}	Not supported
H2a	S-PM → O-BP	5	0.718***	Supported
H2b	S-PM → O-BE	18	0.556***	Supported
	S-PM → O-CE	6	-0.098*	
H2c	S-PM → O-PEI	22	0.529***	Partially supported
	S-PI → O-PEI	1	-0.059 ^{n.s.}	
	S-PER → O-PEI	2	0.123**	
H2d	S-PM → R-PIN	20	0.373***	Partially supported
	S-PI → R-PIN	3	-0.097 ^{n.s.}	
	S-PER → R-PIN	1	0.411***	
H3a	S-SI → O-PEI	1	0.553***	Supported
	S-RM → O-PEI	3	0.742***	
H3b	S-SI → R-PIN	2	0.531**	Supported
H4a	O-BP → O-BE	17	0.526***	Supported
	O-BP → O-CE	2	-0.179**	
	O-CP → O-BE	1	-0.264***	
H4b	O-BP → O-NEI	5	-0.192***	Supported
	O-BP → O-PEI	38	0.556***	
	O-CP → O-PEI	1	-0.499***	
H4c	O-BP → R-NIN	1	-0.092 ^{n.s.}	Partially supported
	O-BP → R-PIN	10	0.409***	
	O-CP → R-NIN	1	0.211***	
	O-CP → R-PIN	1	-0.117*	
H5a	O-BE → O-NEI	1	-0.371***	Supported
	O-BE → O-PEI	34	0.525***	
	O-CE → O-PEI	2	-0.303***	
H5b	O-BE → R-UBE	1	0.132*	Supported
	O-BE → R-PIN	24	0.639***	
	O-CE → R-PIN	9	-0.168**	
H6	O-PEI → R-UBE	1	0.144**	Supported
	O-PEI → R-PIN	44	0.763***	
	O-NEI → R-PIN	1	-0.176***	

Note: Authors' work. ^{n.s.}: not significant.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

variables selected in this study. These paths include “S-RC → O-BP,” “S-RC → O-BE,” “S-PM → O-BE,” and “O-BE → R-PIN.” Although the number of studies related to these paths is sufficient to test the moderating effects, the moderating effects of the moderating variables selected in this study on these paths are not significant and cannot explain the heterogeneity of these paths.

5.2. Theoretical implications

This study not only organized previous empirical studies by combining quantitative and qualitative methods but also tested possible macro-moderating variables. The results and conclusions of this study can provide valuable references for future research.

First, this study sorted and summarized the relevant variables and paths related to the impact of service robots on restaurant consumers in previous studies. Understanding the current status of the research topic of concern is not only conducive to researchers understanding the key topics in existing research but also helps researchers choose future research directions based on existing gaps. For example, through the number of constructs and paths identified in this study, it can be found that in the process of exploring

Table 3. Moderate effect test results.

Path	Moderator	r-weighted	Q-value
S-RC → O-PEI	Percentages of females	0.0173**	122.51***
	Individualism	-0.0094**	
	Power distance	0.0068*	
	Uncertainty avoidance	-0.0047***	
S-PM → O-BP	Indulgence	0.0144*	84.051***
	Power distance	-0.0144*	
S-PM → O-CE	Percentages of females	-0.0193***	31.152***
	Individualism	-0.0293***	
	Uncertainty avoidance	-0.0051***	
	Long term orientation	0.0684***	
	Indulgence	0.0085***	
	Power distance	-0.0121***	
	Education level (university and higher)	0.0227***	
S-PM → O-BE	Power distance	-0.0109*	
S-PM → O-PEI	Uncertainty avoidance	-0.0090**	991.57***
	Indulgence	0.0184***	
	Collection time	0.1947**	
S-PM → R-PIN	Uncertainty avoidance	0.0086**	494.683***
	Long term orientation	0.0061*	
	Indulgence	-0.0057*	
	Collection time	-0.0713**	
O-BP → O-BE	Percentages of females	-0.0193***	474.538***
	Indulgence	-0.0164*	
	Power distance	0.0145*	
	Collection time	-0.3199*	
	Education level (university and higher)	0.0191***	
O-BP → O-PEI	Percentages of females	0.0070*	711.106***
	Long term orientation	0.0070**	
	Indulgence	0.0015**	
	Power distance	-0.0075*	
O-BP → R-PIN	Individualism	-0.0181***	234.034***
	Power distance	0.0161**	
	Marital status (percentage of married)	-0.0833**	
O-BE → O-PEI	Individualism	0.0072*	1054.94***
	Power distance	-0.0078*	
	Marital status (percentage of married)	0.0313***	
O-CE → R-PIN	Percentages of females	-0.0295***	131.294***
	Uncertainty avoidance	-0.0095***	
	Indulgence	0.0114*	
O-PEI → R-PIN	Marital status (percentage of married)	0.0218*	1902.719***

Note: This table only shows results with significant moderating effects; Authors' work.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

the impact of service robots on consumers, existing studies have paid main attention to the characteristics of robots and the internal factors of consumers while ignoring factors related to the environment. Therefore, researchers can continue to explore which environmental factors play a role in the process of service robots affecting consumers. In addition, all negative factors have not been given enough attention. For example, in the stimulus stage, hindrance factors from consumers have received less attention in previous studies. Although the two paths related to obstacles from consumers were not significant in this study, there were many potential paths related to obstacles from consumers worth exploring. However, due to the limited research from this perspective, many potential paths were not tested in this study. Therefore, researchers can continue to explore the hindrance factors that are relevant to consumers in the future and explore the impact of these barriers on consumers. In addition, cost perception, cost evaluation in the

organism stage, negative emotional inclination, and negative intention in the response stage are factors that have not received enough attention in previous studies.

Second, previous empirical studies have paid more attention to consumers' implicit responses, such as consumers' word-of-mouth intention, intention to use and intention to pay more (Belanche et al., 2021; Chuah, Aw, et al., 2022; Molinillo et al., 2023). Limited research has focused on consumers' actual behavior (Hamid et al., 2023). Therefore, the impact of these influencing factors on consumers' actual behavior remains to be explored.

Finally, the effect sizes of most of the moderating variables selected in this study were weak. In particular, although all culture-related variables had significant moderating effects, their moderating effects were weak. Specifically, they had not reached the critical threshold of 0.1 for a small effect size (Nieminen, 2022). However, there was significant heterogeneity in these paths. Therefore, there is still a need to continue to explore the moderating variables that influence these paths in the future. Sample collection time had the strongest moderating effect among the moderating variables in this study. As time passes, the influence of personal motivation for restaurant consumption on positive emotional inclination increases, while the influence of benefit perception on benefit evaluation weakens. This result shows that over time, people pay more and more attention to their inner motivations and needs and adjust their attitudes toward service robots according to their own preferences. Over time, the supporting technology of service robots has developed, and the functions of robots have become increasingly more practical and rich. Consumers have gradually adapted to service robots. In addition, as the novelty fades, the impact of the perceived benefits of the robot for consumers weakens. These moderating effects of time indicate that researchers should pay attention to the impact of time changes when exploring topics related to service robots in the future. Longitudinal studies may be more effective for researchers to explore the impact of service robots on consumers.

5.3. Practical implications

The conclusions of this study can also bring some inspiration to restaurant practitioners. First, restaurant managers, when considering employing service robots while paying attention to the cost of use, must also control the characteristics and quality of service robots. In particular, attention should be given to robot features related to functionality, appearance and novelty. These features can not only enhance consumers' perception of benefits and benefit evaluations but also reduce consumers' perception of costs and cost evaluations and further enhance consumers' positive attitudes. The improvement of consumer attitudes will increase consumers' willingness to pay more and their willingness to revisit (Chuah, Aw, et al., 2022; Odekerken-Schröder et al., 2022). Therefore, managers may reduce or offset the costs of hiring robots within a reasonable range by enhancing the benefits brought by consumers' positive

intentions. In addition, the overall atmosphere of the restaurant, including the brand atmosphere and the working atmosphere generated by the cooperation between human employees and robot employees, is also an important antecedent that affects consumer intentions (Hlee et al., 2023; Kim et al., 2023). Therefore, restaurant managers can adjust the appearance of the restaurant and robots based on brand culture to enhance the sense of brand atmosphere. Managers should also reasonably allocate the work of service robots and human employees. Effective allocation here not only means letting service robots and human employees handle their work separately but also strengthening the interactive cooperation model between the two, to display a good working atmosphere and thus enhance consumers' positive emotional inclination.

As many studies related to service robots have suggested, managers should also pay attention to the importance of social media (Hwang et al., 2024; Zemke et al., 2023). By using social media to promote restaurant robots, the public's recognition and acceptance of service robots could be improved, thereby increasing consumers' personal motivation to use service robots. Additionally, the promotional content on social media will also affect the views of the groups around consumers regarding service robots, thereby affecting consumers' attitudes and intentions toward service robots. Therefore, managers should make effective use of social media and formulate appropriate marketing strategies based on the characteristics of the target consumer groups.

In addition to improving the positive impact of service robots on consumers, restaurant managers should not ignore some factors that may have negative effects. Some factors have been found to weaken consumers' positive intentions and enhance consumers' negative intentions. For example, some consumers believe that interactions with robots cannot meet their social needs and weaken their positive attitudes toward robots (Sung & Jeon, 2020; Zemke et al., 2023). Some consumers believe that service robots are not easy to use, which weakens their intention to go to robot restaurants and use service robots in the future (Huang et al., 2024; Seo & Lee, 2021). These negative factors are all related to the functions and designs of service robots. Therefore, at a stage where service robot-related technologies still need to be improved, restaurant managers should not rely too much on service robots and should instead deploy sufficient human employees to alleviate the negative effects caused by the limitations of service robots.

Finally, managers should also be aware that consumers are becoming increasingly comfortable with service robots over time. The impact of the perceived benefits of service robots is gradually weakening. At the same time, consumers are increasingly influenced by personal motivations, such as the need for novelty and social identity. Therefore, in the process of restaurant management, managers should not simply pursue the novelty of the appearance and the uniqueness of the functions of service robots but also pay more attention to how to use robots to provide consumers with personalized services that better meet their needs, thereby

improving consumer satisfaction and positive intentions. In addition, managers should also conduct regular return visits to promptly understand the changes in consumer needs and how their views on service robots evolve over time.

In short, restaurant managers can make reasonable work arrangements and deployments for service robots based on the conclusions of this study. Managers can also determine the factors that affect consumers' positive and negative intentions based on the research conclusions and attract new consumers and retain loyal customers through reasonable management.

6. Limitations of this study

Affected by the research topic, research data and other objective factors, this study inevitably has certain limitations. First, this study was limited by the impact of service robots on consumers in restaurants, so the research conclusions might not be applicable to other types of service scenarios. Future research can conduct research in other hospitality scenarios, such as conducting a meta-analysis of the impact of service robots on consumers in hotel scenarios and tourism scenarios. This approach is conducive not only to enriching relevant research in hospitality industry scenarios from a holistic perspective and identifying the common characteristics of the impact of service robots on consumers in hospitality scenarios but also to discovering new research topics through the differences in different types of hospitality scenarios.

Second, this study was based on data from existing empirical studies. The quantity and quality of existing research data would affect the conclusions of this study. Due to time constraints and literature screening principles, the number of studies ultimately included in this study was limited, and some studies failed to provide exact sample data, which resulted in some paths being unable to test the moderating effect. In the future, based on this study, researchers can continue to conduct regular meta-analysis studies on this topic. This can not only compensate for the limitation caused by the insufficient number of studies but also track the development of this research topic and explore more potential variables. In addition, as the number of studies increases in the future, other potential moderating variables can be explored in future meta-analysis studies, such as the specific types of service robots and the generational characteristics of consumer groups.

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