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How efficient is your robot server? Examining the antecedents of perceived efficiency of service robots in restaurants

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Purpose

This study aims to examine the factors shaping the perceived efficiency of service robots in restaurant environments, as well as the mediating roles of functional, emotional, social, and epistemic values.

Design/methodology/approach

A survey (n = 155) was conducted with restaurant customers who had prior experience with robotic service. Data were analysed using regression and mediation analysis (PROCESS model) in SPSS 29.

Findings

Personalization, authenticity, and the service environment significantly increased perceived efficiency. Among the perceived value dimensions, only functional and epistemic values were found to mediate these relationships significantly.

Originality/value

This study highlights the importance of practical utility and novelty in shaping customer evaluations of service robots. Theoretically, it integrates the Technology Acceptance Model (TAM), Service-Dominant Logic (SDL), and Expectancy-Confirmation Theory (ECT) to offer a more detailed understanding of customer–robot interaction in the context of robotic restaurant services. Practically, it provides guidance for designing robotic services that enhance both functional and epistemic value.

Keywords: service robots, robotic restaurants, efficiency, personalization, service authenticity, perceived value, service environment

1. Introduction

The service robot market is expanding rapidly, with Japan expected to witness a threefold increase in robots across various service industries such as restaurants by 2030 (Job, 2025). Integrating service robots represents a strategic paradigm shift by the restaurant industry to optimize operational efficiency (Chen & Girish, 2023). It is estimated that over 80% of restaurant positions can be automated (The Adecco Group, 2020), and the global service robot market is projected to be valued at more than US\$21 billion by 2026 (Mordor Intelligence, 2022). These projections highlight the need for academic research to support the industry's transition towards the (more) robotic future.

The research agenda concerned with evaluating the effect of service robots' integration into restaurant operations is rapidly emerging (Berezina et al., 2019; Garcia-Haro et al., 2020; Oğan (2024). A dedicated line of research focuses on how restaurant customers perceive and evaluate service robots, given that (positive) consumer feedback determines the speed and extent to which restaurateurs will embrace the robotization (Park et al., 2024). Studies have examined how robots can affect customer trust in the robotic service provision (Seo & Lee, 2021), patronization intentions (Molinillo et al., 2023), and potential for value co-creation (Zhang et al., 2022).

Despite the progress made so far in research on the relationship between service robots and restaurant guests, existing studies have focused on constructs such as customer trust (Seo & Lee, 2021), satisfaction (Chang, 2024), intention to use (Molinillo et al., 2023), and perceived service quality (Wu et al., 2025). Some research has examined customer perceptions of robot performance or efficiency-related attributes; however, these studies have generally considered efficiency as a secondary or implicit outcome (Zhang et al., 2022; Kwak et al., 2021). What remains insufficiently explored is a direct, multidimensional investigation of the specific factors and mechanisms that influence perceived efficiency. This study seeks to address this

gap by identifying the key drivers of perceived efficiency and examining how different value dimensions mediate these effects.

To understand customers' perceptions of efficiency in robot-delivered services, it is essential to identify the experiential factors that inform these evaluations. Prior literature underscores personalization (Mittal & Lassar, 1996), service authenticity (Kim, 2021), and the service environment (Rauch et al., 2015) as fundamental determinants of service assessments. Personalization, defined as the extent to which a service is tailored to individual needs, improves perceived usefulness and reduces cognitive effort (Chandra et al., 2022; Wang et al., 2017). In the context of robot–customer interactions, adaptive and need-based responses facilitate goal attainment and thereby enhance perceptions of efficiency. Service authenticity refers to the perceived genuineness and meaningfulness of the interaction (Yi & Medler-Liraz, 2013). Although robot encounters lack human agency, authentic communication and natural interaction patterns can foster trust and relevance, ultimately improving assessments of functional performance. Service environment provides the contextual setting for the interaction and acts as a facilitator of the service process (Bitner, 1992). In a robotic restaurant, an appropriately designed environment supports task completion and flow, and thus reinforcing perceived efficiency (Guan et al., 2022). Collectively, these factors constitute salient antecedents of efficiency perceptions in robot service encounters and are examined in the current research. This study has also set to uncover the mediating role of the perceived value dimensions, including functional, emotional, social, and epistemic (Pihlström & Brush, 2008), in the relationship between robot efficiency and its antecedents. While previous research on robotic services has examined the mediating role of perceived value, it has predominantly conceptualized perceived value as a two-dimensional construct, comprising utilitarian and hedonic values (see for example, Chang, 2024; Wu et al., 2024). While this approach provides basis for further research, it oversimplifies the complex ways in which consumers evaluate

service robots. Expanding the framework to include functional, social, emotional, and epistemic value dimensions by the current research offers a more granular and comprehensive understanding of the mediating effect of each value dimension in the relationship between robot efficiency and its determinants. By examining the mediating role of multidimensional value, this study examines *why* service robot interactions are considered efficient by restaurant guests, thus moving beyond simplistic observations of *what* works best.

Given the subjective nature of customer perceptions in service evaluations in such a dynamic consumption context as restaurants, this study recognizes that socio-demographic factors may influence these evaluations. Specifically, such socio-demographic variables as age, income, and parental status can exert controlling effects on the interplay between personalization, authenticity and service environment and perceived efficiency of service robots. For instance, younger generations may exhibit distinct preferences towards service robots compared to older demographics (Ma et al., 2023). Likewise, higher-income individuals may prioritize functional and social values of service robots (Chuah et al., 2022) and parents may emphasize robotic efficiency when providing child-friendly services (Peng et al., 2024). By incorporating these socio-demographic variables into the analysis, this study aims to enhance an understanding of how customer responses to service robots vary depending on their socio-demographic profile.

From a theoretical perspective, by identifying and examining personalization, perceived authenticity, and the service environment as key antecedents of service robot efficiency, the study offers new theoretical insights into how specific experiential factors shape the dynamics of customer–robot interactions in restaurant settings. Also, by examining the mediating role of four perceived value dimensions, this study extends the Technology Acceptance Model (TAM) beyond its traditional focus on perceived usefulness and ease of use, incorporating the complex nature of customer perceived value as advocated by Service-Dominant Logic (SDL).

Lastly, by exploring the dynamic interplay between customer expectations and experiences of service robots, this study provides a more nuanced understanding of the role played by customer (dis)satisfaction, which is driven by a mismatch between expectations and experiences as indicated in Expectancy-Confirmation Theory (ECT), in robotic service encounters.

From a practical perspective, this study outlines directions for optimizing the integration of service robots in restaurant operations. By establishing the mechanisms through which personalization, authenticity, and service environment can influence perceived efficiency, restaurateurs can (re)design service encounters to enhance customer satisfaction. Likewise, by examining the mediating effect of perceived value dimensions, the study enables restaurateurs to refine their service strategies based on the influential value dimension(s).

2. Literature review and hypotheses development

2.1. Effect of personalization, service authenticity, service environment on perceived efficiency

Personalization reflects a robot's capacity to imitate human-like responsiveness and provide to evolving demands in hospitality services (Licardo et al., 2024). Personalized interactions increase perceived usefulness (Wong & Wong, 2024), influence how customers evaluate responsiveness (Verhagen et al., 2014), timeliness (Kim & Kim, 2025), and reliability (Salih et al., 2025) of service robots, shaping their perceived efficiency. The ability of service robots to adapt their behaviour and interactions to meet individual customer needs can increase perceptions of efficiency (Berezina et al., 2019). Therefore, the following hypothesis is formulated:

H1. Personalization positively influences perceived efficiency of service robots.

Service authenticity, defined as the perception of genuine, sincere, and contextually appropriate service behaviour (Grandey et al., 2005), plays a crucial role in shaping customers' evaluations of robotic service interactions. In line with the Expectancy-Confirmation Theory (ECT), customers can approach a service interaction with specific expectations about how a service robot should perform (Albtoosh et al., 2024). When a robot delivers responsive and contextually appropriate service, these expectations are confirmed, signalling reliability and enhancing perceived efficiency (Veera Raghavan, 2024; Zhang et al., 2022). In parallel, the Technology Acceptance Model (TAM) suggests that perceptions of ease of use and usefulness influence technology adoption (Venkatesh & Davis, 2000). Authentic service contributes to these perceptions by enabling smooth, intuitive, and human-like interactions, reducing cognitive effort, minimizing errors, and increasing trust in the robot's performance. Together, these mechanisms indicate that service authenticity not only aligns with customer expectations but also enhances their perception of the robot's functional efficiency (Haugeland et al., 2022). Based on this reasoning, we propose the following hypothesis:

H2. Service authenticity positively influences perceived efficiency of service robots.

The service environment consists of physical, ambient, and social factors that shape customer experiences in a service setting (Lin & Liang, 2011). Design, ambience, and facility quality within a service environment influence customer perceptions of service efficiency (Durna et al., 2015). A fashionable interior and up-to-date facilities create a foundation for more efficient interactions with robotic servers (Garcia-Haro et al., 2020). A well-structured environment can minimize distractions and enhance customer focus on service interactions, reinforcing efficiency perceptions (Hyun et al., 2024). The following hypothesis is, accordingly, developed:

H3. Service environment positively influences perceived efficiency of service robots.

2.2. Mediating role of perceived value

2.2.1. Perceived value as a mediator between personalization and perceived efficiency

The service-dominant logic (SDL) posits that value arises from dynamic interactions between service providers and recipients, rather than residing inherently within the service or product itself (Vargo et al., 2008). In robotic restaurant environments, personalization functions as a service design approach where the robot adjusts its behaviours such as greetings, tone, or movement patterns to individual customers, thereby co-creating value through these customised interactions (Balaji et al., 2025). This personalization can contribute to emotional value by evoking feelings of comfort, familiarity, and enjoyment. For example, a robot that remembers a customer's preferred table or greets them with a familiar tone simulates care, reducing emotional friction and making the interaction more human-like (Saunderson & Nejat, 2019). Such emotionally responsive interactions can improve perceptions of efficiency, especially in service environments where emotional comfort is vital to satisfaction, such as dining (Mende et al., 2019).

Personalization can add social value. For instance, dining with service robots may be regarded as innovative or elite, reinforcing customers' self-image as modern or tech-savvy individuals (Zhang et al., 2021). Even limited personalization, like a robot recognising a returning customer, can allow patrons to project a sense of social distinction, increasing their belief that the service is efficient and desirable (Husain et al., 2023).

Service robots' personalization can enhance functional value by delivering greater accuracy and expedited service. For example, adjusting delivery speed to suit customer preferences or navigating efficiently around specific tables can reduce wait times and service disruptions. These practical improvements can strengthen the perception of the robot as a capable and efficient service provider (Zhang et al., 2025).

Personalized robotic service can augment epistemic value through novelty, surprise, and knowledge gain. Customers interacting with robots that adapt dynamically via personalized greetings or suggestions may find the encounter intellectually engaging or entertaining (Aoudni et al., 2025). This supports perceptions of the robot as not only functional but also intelligent and progressive (Xiong et al., 2025). On these grounds, the following hypothesis is posited:

H4. The influence of personalization on the perceived efficiency of service robots is mediated by perceived value facets, including (a) emotional value, (b) social value, (c) functional value, and (d) epistemic value.

2.2.2. Perceived value as a mediator between authenticity and perceived efficiency

Authentic service interactions evoke positive emotional responses such as comfort (Pitardi et al., 2024) and trust (Li et al., 2024), helping customers feel more at ease with robotic service (Lu et al., 2021). By fostering emotional connections, authenticity enhances emotional value, which strengthens customers' perceptions of robotic efficiency. Therefore, emotional value may mediate the relationship between perceived authenticity and perceived efficiency.

Customers who view robotic service as a source of social recognition and prestige tend to place greater value on their interactions (Schultz & Kaiser, 2025). Authentic robotic service thus may enhance social value by conveying symbolic benefits such as status and social approval, which can improve overall service evaluations, including perceived efficiency. Consequently, authenticity may indirectly influence perceived efficiency through social value, suggesting that social value potentially mediates this relationship.

Authentic robotic service enhances confidence in service accuracy (Balaji et al., 2025) and consistency (Chen et al., 2025). Such authenticity fosters perceptions of reliability (Liu et al., 2025), which in turn strengthen perceived efficiency (Balaji et al., 2025). As these qualities

reflect key aspects of functional value, it is plausible that functional value mediates the relationship between perceived authenticity and perceived efficiency.

Authentic robotic service evokes novelty and engagement, stimulating customer interest and curiosity (Nguyen et al., 2025). Perceived authenticity encourages appreciation of the service's innovative features, enhancing perceived efficiency (Gong, 2025). These cognitively stimulating experiences reflect epistemic value, which may mediate the link between authenticity and perceived efficiency. On these grounds, the following hypothesis is proposed:

H5. The influence of service authenticity on perceived efficiency of service robots is mediated by perceived value facets, including (a) emotional value, (b) social value, (c) functional value, and (d) epistemic value.

2.2.3. Perceived value as a mediator between service environment and perceived efficiency

A well-designed service environment with modern aesthetics and an inviting atmosphere enhances emotional engagement (Chen, 2025), making interactions with robotic servers efficient (Guan et al., 2022). Hence, emotional value potentially mediates the relationship between service authenticity and service environment with perceived efficiency.

A well-designed service environment fosters exclusivity and status (Horng et al., 2025), shaping customers' social identity during interactions with robotic service (Gong et al., 2025). By enhancing social value, the service environment may influence customers' perceptions of robotic service efficiency. Therefore, social value potentially mediates the relationship between service environment and perceived efficiency.

An optimized service environment enhances functional value by enabling efficient service delivery, minimizing wait times, and improving the overall customer experience (Khenfer & Trendel, 2025). This increased functional value builds customer confidence in the service's ability to fulfil their needs, thereby strengthening perceptions of efficiency (Van Huy et al.,

2025). Accordingly, functional value may mediate the relationship between the service environment and perceived efficiency.

A futuristic, tech-driven service environment enhances epistemic value by enabling customers to explore advanced AI-driven interactions (Rasool & Bhat, 2025). This stimulates engagement and reinforces positive perceptions of service efficiency (Horng et al., 2025). Therefore, epistemic value may mediate the effect of service environment on perceived efficiency. These insights support the following hypothesis:

H6. The influence of service environment on the perceived efficiency of service robots is mediated by perceived value facets, including (a) emotional value, (b) social value, (c) functional value, and (d) epistemic value.

2.3. Role of sociodemographic characteristics in perceived efficiency

An early meta-analysis (Hancock et al., 2011) of research on human-robot interaction indicated that demographics played a minimal role in this relationship. However, recent studies on patronage intentions suggest that demographic attributes significantly influence customers' willingness to pay for robotic restaurants (Chuah et al., 2022; Ivanov & Webster, 2021). One explanation is that customers' understanding of emerging technologies, such as social robots, is shaped more by social interactions than scientific or technical knowledge (Sabanović, 2010). Their perceptions and valuation of technology are driven by prevailing social attitudes rather than direct expertise (Forgas-Coll et al., 2022).

Age can affect how individuals evaluate service robots. Younger generations, more accustomed to technological advancements, may perceive robotic services as more efficient and intuitive due to generational differences (Kim et al., 2021). In contrast, older customers may require more cognitive effort when interacting with robotic systems, potentially leading to different evaluations of service efficiency (Čaić et al., 2018). However, recent research (So et al., 2024)

found no significant differences among age groups regarding trust in or receptivity toward service robots. Additionally, some studies indicate that humanoid robots enhance expected service quality, except for individuals with low technology readiness (Yoganathan et al., 2021).

Income levels may also influence perceived efficiency. Higher-income individuals with greater exposure to premium technological services may expect higher efficiency from robotic interactions (Chuah et al., 2022). In contrast, lower-income individuals may evaluate efficiency based on accessibility, affordability, and ease of use (Khowaja et al., 2024). Research suggests that senior customers' perceived value positively influences their attitudes toward robot service restaurants, with hedonic and social motivations enhancing this effect (Kwak et al., 2021). However, the impact varies by income level: hedonic motivation plays a more significant role in shaping perceived value for low-income senior customers.

Parental status may also contribute to variations in perceptions of robotic service efficiency. Parents may assess efficiency based on service speed, reliability, and the ability of robotic servers to cater to family needs (Seyitoğlu & Ivanov, 2022). On the other hand, non-parents may prioritize personalized service experiences and the social or epistemic value of robotic interactions (Wu et al., 2021).

Despite these insights, the literature remains inconclusive, and it is important to investigate the role of demographics in shaping perceptions of service robot efficiency further. Hence, the following hypothesis is proposed:

H7. There are significant differences in the perceived efficiency of service robots among age groups (1), income groups (2), and parental status groups (3).

The hypotheses are visually presented in Figure 1.

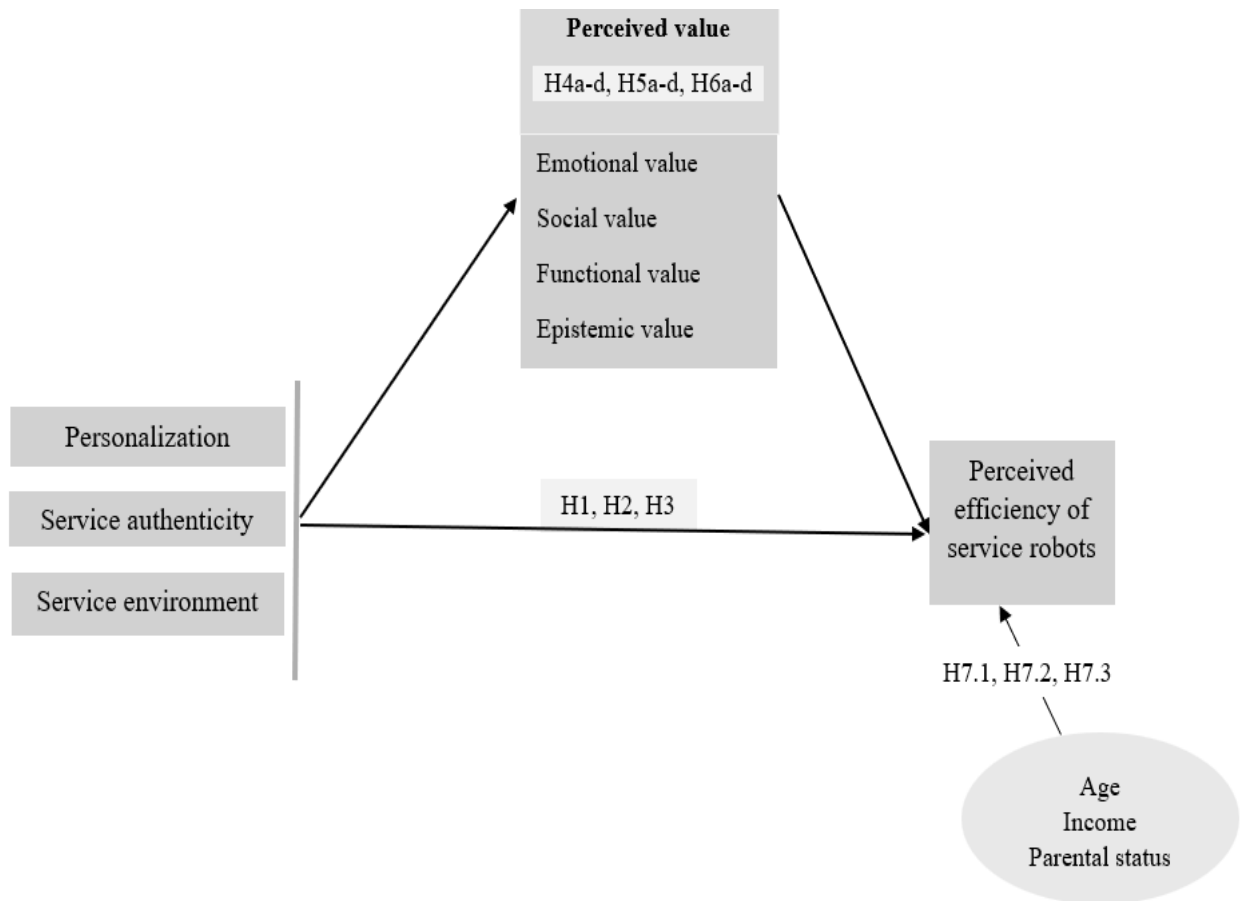


Figure 1. Research framework
(Source: Authors' own work)

3. Methods

3.1. Survey instrument

Data were collected by the survey method. The instrument was composed of 8 constructs, including perceived personalization, service authenticity, service environment, perceived efficiency, emotional value, social value, functional value, and epistemic value (Table 1). Perceived personalization (3 items) and perceived efficiency (3 items) were adapted from Prentice & Nguyen (2021). Each of the four perceived values was measured by 3 items adapted from Chuah et al. (2022). Service authenticity (3 items) and service environment (3 items) were adapted from Song et al. (2022) and Guan et al. (2022), respectively. All constructs were measured with a 7-point Likert-type scale.

All constructs demonstrated internal reliability, as their Cronbach's alpha values exceeded the threshold of 0.7. The mean scores indicated that the study participants supported positive statements about personalization, efficiency, service authenticity, service environment, emotional value, functional value, and epistemic value (mean scores ranging from 4+ to more than 5+. Social value, meanwhile, received low mean scores (less than 3), which indicated that dining in a robotic restaurant was perceived to enhance customers' social status.

Table 1. Measurement items

(Source: Authors' own work)

Constructs and measurement items	Mean	SD	Cronbach's alpha
Personalization			0.881
Robotic waiters in the restaurant that I visited last time were capable of addressing a wide range of customer needs.	4.85	1.634	
Robotic waiters in the restaurant that I visited last time were flexibly adapted to meet evolving customer demands.	4.24	1.561	
Robotic waiters in the restaurant that I visited last time were versatile in catering to customers' requirements.	4.33	1.638	
Service authenticity			0.897
Robot waiters' services in the restaurant that I visited last time felt genuine.	4.96	1.374	
Robotic waiters' services in the restaurant that I visited last time appeared sincere.	4.40	1.461	
Robotic waiters' services in the restaurant that I visited last time seemed authentic.	4.24	1.453	
Service environment			0.818
The interior of the robotic restaurant that I visited last time is fashionable.	4.67	1.139	
The robotic restaurant that I visited last time has up-to-date facilities.	5.11	1.117	
The atmosphere of the robotic restaurant that I visited last time is cheerful.	4.80	1.339	
Efficiency			0.829
Robotic waiters in the restaurant that I visited last time were responsive to my requests.	5.36	1.078	
Robotic waiters in the restaurant that I visited last time provided service in a timely manner.	4.98	1.354	
Robotic waiters in the restaurant that I visited last time provided reliable service.	5.36	0.988	
Emotional value			0.904

Interacting with robots in the restaurant that I visited last time was fun.	5.47	1.464	
Interacting with robots in the restaurant that I visited last time was entertaining.	5.05	1.603	
Interacting with robots in the restaurant that I visited last time was enjoyable.	4.82	1.516	
Social value			0.903
Dining at a robotic restaurant could provide me with social approval.	3.47	1.597	
Dining at a robotic restaurant could improve the way others perceive me.	2.89	1.696	
Dining at a robotic restaurant could help me make a good impression on others.	2.93	1.762	
Functional value			0.745
Robotic waiters in the restaurant I visited last time enhanced my dining experience.	4.56	1.437	
Robotic waiters in the restaurant I visited last time reduced my waiting time.	4.75	1.468	
Robotic waiters in the restaurant I visited last time delivered consistent services.	4.22	1.462	
Epistemic value			0.860
Dining at the robotic restaurant last time satisfied my sense of curiosity.	5.35	1.336	
Dining at the robotic restaurant last time gave me an opportunity to learn new things.	4.87	1.504	
Dining at the robotic restaurant last time was a novel experience in my life.	5.36	1.379	

3.2. Data collection

The target population was restaurant customers who have had a robotic dining experience.

Participants were recruited through the Prolific platform using the purposive sampling. The eligibility criteria required respondents to confirm that they had dined at a restaurant with service robots within the past 12 months. Prolific was chosen for its proven effectiveness in reaching international, demographically diverse, and experience-specific samples in hospitality research (Chuah et al., 2022). The screening question “Have you dined in a robotic restaurant in past 12 months?” was used to filter only those with relevant service encounters. To recruit participants, a Qualtrics-based questionnaire survey was launched on Prolific in January 2025. An a priori power analysis was conducted using G*Power 3.1 (Faul

et al., 2007) to determine the minimum sample size required for the study's primary analysis. For multiple linear regression with 8 predictors, assuming a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and power = 0.90, the required sample size is 136. Given the calculation and the fact that the number of robotic restaurants around the world is limited (Seyitoglu & Ivanov, 2022), 155 responses were collected from those who have dined at a robotic restaurant across different regions, including the United States (32.9%), Singapore (31.61%) and Japan (35.48%). Recent studies on service robots, such as Lu et al. (2024), which involved 144 participants in Study 1 and 191 participants in Study 2, and Kim et al. (2024), which included 162 participants in Study 1 and 129 participants in Study 2, further support the adequacy of the sample size in the current research. Table 2 provides more details on the participants.

Table 2. Participants (N=155)

(Source: Authors' own work)

Demographic characteristics		N	%
Gender	Male	82	52.9
	Female	73	47.1
Age	18-25	27	17.42
	26-35	49	31.61
	36-45	35	22.58
	46-55	23	14.84
	55+	21	13.55
Parental status	Having children	89	57.42
	No children	66	42.58
Monthly household income	≤\$2,000	18	11.61
	\$2,001- \$3,000	45	29.03
	\$3,001 - \$4,000	68	43.87
	\$4,000+	24	15.48

3.3. Common method bias

Common method bias refers to the error variance shared across variables resulting from the measurement method itself, which can compromise construct validity in quantitative research (Drost, 2011). Harman's single-factor test revealed that the first factor accounted for 20.75%

of the total variance, which is below the 50% threshold (Podsakoff et al., 2003). Therefore, common method bias did not pose a concern for the study's validity.

3.4. Data analysis

The data were analyzed using SPSS 29. Multiple regression analysis was performed to test H1, H2, and H3. Hayes PROCESS model 4 was applied to test H4a-d, H5a-d, and H6a-d. To test H7.1, H7.2, and H7.3, ANOVA and post-hoc tests were conducted.

4. Results

4.1. Antecedents to service robots' efficiency

The influences of personalization (H1), service authenticity (H2), and service environment (H3) on perceived efficiency of service robots were examined using multiple regression analysis. H1 (standardized $\beta=0.285$, $SE=0.032$, $t=6.648$, $p < 0.001$), H2 (standardized $\beta=0.195$, $SE=0.033$, $t=4.547$, $p < 0.001$), H3 (standardized $\beta=0.329$, $SE=0.042$, $t=7.733$, $p < 0.001$).

4.2. Mediating effect of perceived value facets

The mediating effect of perceived value facets, including emotional value (a), social value (b), functional value (c), and epistemic value (d) on the relationship between personalization (H5), service authenticity (H6), and service environment (H7) on the perceived efficiency of service robots was tested using Hayes PROCESS model 4 with 95% confidence intervals, and 5000 bootstrap samples. The results (Table 3) showed that only functional value and epistemic value partially mediated the effects of personalization, service authenticity, and service environment on the perceived efficiency of service robots. Accordingly, only H5c-d, H6c-d, and H7c-d were supported.

Table 3. Mediating results**(Source: Authors' own work)**

Paths	Direct effect				Indirect effect		
	Effect	SE	CI _{95%} [LLCI, ULCI]	p	Effect	SE	CI _{95%} [LLCI, ULCI]
Pers→EV→Eff	0.189	0.033	[0.1246, 0.2536]	***	0.0103	0.0229	[-0.0347, 0.0570]
Pers→SV→Eff					-0.0152	0.0101	[-0.0371, 0.0024]
Pers→FV→Eff					0.1153	0.0248	[0.0683, 0.1660]
Pers→EPV→Eff					0.0630	0.0232	[0.0216, 0.1126]
SA→EV→Eff	0.126	0.034	[0.0586, 0.1929]	***	0.0198	0.024	[-0.0277, 0.0685]
SA→SV→Eff					-0.0145	0.0098	[-0.0363, 0.0028]
SA→FV→Eff					0.1274	0.0273	[0.0771, 0.1844]
SA→EPV→Eff					0.0675	0.0233	[0.0243, 0.1157]
SE→EV→Eff	0.2285	0.0502	[0.1298, 0.3271]	***	0.0354	0.0365	[-0.0360, 0.1090]
SE→SV→Eff					-0.0389	0.0196	[-0.0794, 0.0029]
SE→FV→Eff					0.1922	0.0397	[0.1155, 0.2715]
SE→EPV→Eff					0.0906	0.0405	[0.0119, 0.1694]
Notes: Pers: personalization, Eff: efficiency, EV: emotional value, SV: social value, FV: functional value, EPV: epistemic value ***p<0.0001							

4.3. Differences in perceived efficiency among age, income, and parental status groups

Analysis of variance (ANOVA) was conducted to examine the perceived efficiency of service robots differs among age (H7.1), income (H7.2), and parental status (H7.3) groups. The ANOVA results revealed that the perceived efficiency significantly differed by age ($F(4,$

150)=3.786, $\eta^2=0.036$, $p=0.005$), income ($F(3, 151)=2.950$, $\eta^2=0.021$, $p=0.03$), and parental status ($F(1, 153)=3.386$, $\eta^2=0.019$, $M_{\text{having children}}=5.22 < M_{\text{no children}}=5.40$, $p=0.04$). The Tukey-HSD post-hoc tests were performed to examine what age group(s) and income group(s) differed from the others in the perceived efficiency of service robots. The results showed that the age group 36-45 was significantly different from the groups of 18-25 (mean difference=0.55559, SE= 0.17655, $p=0.15$) and 46-55 (mean difference=0.38498, SE= 0.13364, $p=0.034$). The income group USD4,000+ was found to be significantly different from the $\leq$ USD2,000 counterpart (mean difference=0.37139, SE= 0.14051, $p=0.042$). Therefore, H7.1, H7.2, and H7.3 were supported.

5. Discussion

This study examined the factors influencing customers' perceived efficiency of service robots in restaurants, revealing that personalization, service authenticity, and the service environment all significantly contribute to higher perceived efficiency. This suggests that when robots are tailored to individual preferences, provide a sense of genuine service, and operate seamlessly within a well-designed restaurant environment, customers perceive them as more effective. For example, a robot that remembers a customer's preferred drink and delivers it without prompting (i.e., personalization) is considered more efficient which may increase customer intention to revisit. Likewise, a robot that communicates naturally, using a human rather than a mechanical voice (i.e., perceived authenticity), creates a more positive impression on restaurant guests. Lastly, a restaurant with a logical layout, clear pathways for robots to follow, and designated robot docking stations (i.e., service environment) streamlines robot navigation, thus contributing to their perceived efficiency by customers.

Service robots' personalization (Wu, 2025), their perceived service authenticity (Yang et al., 2024) and the service environment in which they operate (Hlee et al., 2023) can affect

restaurant guests' attitudes and behaviour. This study provides empirical evidence to demonstrate this effect on perceived efficiency of robotic service which can contribute to trust building and prompt patronization intentions. The results of this study thus respond to the call for more research on the complex antecedents of positive customer evaluations of service robots in restaurants as set by Berezina et al. (2019).

This study also explored the mediating role of perceived value, specifically examining the effect of functional, social, emotional, and epistemic value on perceived efficiency of service robots in restaurants. Unlike past research which has treated perceived value of robotic service as a simple, unidimensional construct (Hong et al., 2023; Kwak et al., 2021; Zhang et al., 2022), the current research considered this factor as multidimensional and examined the role of each value dimension in perceived efficiency. The results suggest that functional and epistemic values partially mediate the effects of personalization, service authenticity, and the service environment on guests' perceptions of service robot efficiency. These findings suggest that customers assess service robot efficiency primarily through practical utility and the novelty of the learning experience. Seamless functionality and engaging interactions are key drivers of perceived efficiency. For example, a service robot that delivers orders swiftly and accurately enhances functional value by reducing wait times and potential complaints. Similarly, a robot that explains unfamiliar menu items or details ingredient origins contributes epistemic value, enriching the dining experience through informative engagement. These results enhance an understanding of the key dimensions of perceived value that have the foremost potential to contribute to positive customer evaluations of robotic restaurants.

Notably, although the mediating role of social value was not supported, the consistently negative coefficients for social value suggest that robotic restaurants are not perceived as venues that confer social approval, prestige, or status. Unlike high-end or human-centred service settings, where social signalling contributes positively to the customer experience (e.g.,

being seen at an exclusive restaurant), robotic restaurants appear to be experienced primarily as practical, functional, or novelty-driven environments. This likely reflects the current cultural positioning of service robots as functional tools rather than aspirational symbols, limiting their potential to generate social capital.

Lastly, this study examined the impact of such socio-demographic factors as age, income, and parental status of restaurant guests, on their perceived efficiency of service robots. The results indicated that perceived efficiency varied significantly across different age and income groups, thus confirming the literature that consumer perceptions of robotic efficiency were not uniform (Chuah et al., 2022; Ma et al., 2023; Peng et al., 2024). Middle-aged and higher-income customers were found to exhibit different expectations or experiences compared to those of other age groups and income levels, thus prompting distinct evaluations of service robots. Potential explanations can rest in varying levels of familiarity with robotic technology, service expectations, or lifestyle needs. For example, middle-aged customers, who are often time-constrained, may prioritize the robot's ability to expedite service, thus emphasizing the importance of functional value. In contrast, younger customers, while being more open to trying robotic technologies, may be less likely to appreciate the functional value, focusing on emotional or social values instead. Higher-income customers may anticipate a seamless and (more) sophisticated experience provided by service robots, thus reflecting their lifestyle. Parental status can also influence perceived efficiency of service robots, with differences observed in the current study between customers with and without children. This suggests that parents may have specific concerns or priorities related to childcare, such as the safety, hygiene, or convenience of service robots, that affect their perception of efficiency. Parents with young(er) children may appreciate service robots delivering food quickly (i.e., functional value) or entertaining children (i.e., emotional value).

The results of the current study thus offer a novel perspective on the role of socio-demographic variables in customer evaluations of service robots in restaurants.

5.1. Theoretical implications

This study contributes to theory and practice with a more nuanced understanding of the antecedents of perceived efficiency of service robots by restaurant guests. From the theoretical perspective, by leveraging insights from the Technology Acceptance Model (TAM), Service-Dominant Logic (SDL), and Expectancy-Confirmation Theory (ECT), this study extends beyond traditional applications of TAM by demonstrating the important mediating role of perceived functional and epistemic values in building customer perceptions of service robots' efficiency. This suggests that, in addition to the core TAM's propositions that have been well established in the literature on the perceptions of technological innovations, restaurant guests evaluate service robots not only on perceived usefulness and ease of use, but also on the perceived tangible benefits and intellectual stimulation which these robots offer. This is aligned with the core value co-creation principles of SDL which highlights the importance of converging SDL with TAM to offer a more nuanced and, concurrently, more comprehensive perspective on the determinants of positive customer evaluations of service robots in the restaurant industry.

By revealing that functional and epistemic values, rather than emotional or social values, predominantly mediate the effects of personalization, authenticity, and service environment on perceived efficiency, this current study provides a more detailed understanding of customer value perceptions in technology-mediated service encounters, such as foodservice provision. This supplements the traditional viewpoint on restaurant service design and delivery that advocates the importance of emotional and social factors for effective service interactions. This current study shows that, in the context of robotic service provision, practical utility and

novelty may be valued by restaurants guests as equally if not more important than emotional and social factors. This highlights the need to integrate SDL in future research on the antecedents of customer evaluations of service robots in restaurants where its propositions should be converged with the postulates of TAM to develop a more comprehensive analytical framework.

Lastly, the study's integration of the ECT perspective in research on the success of the restaurant industry's adoption of robotic services sheds light on how pre-existing customer expectations, particularly regarding personalization and authenticity, but also functional performance and unique experiences attributed to service robots, can influence post-service evaluations. This underlines the importance of understanding these expectations, especially among different socio-demographic customer groups. This study demonstrates the potential influence of such socio-demographic factors as age, income level, and parental status on the consumer evaluation of service robots' efficiency. This adds granularity to the understanding of human-robot interaction; this also highlights the importance of acknowledging customer heterogeneity in theoretical models and practical applications on the prerequisites of customer acceptance/rejection of technological innovations in the restaurant industry.

5.2. Practical implications

From a practical perspective, this study offers several recommendations for restaurant managers seeking to integrate service robots into their operations more effectively. The results extend beyond general advice to industry practitioners but strive to establish priorities for investment and service design.

First, while personalization, service authenticity, and the service environment all significantly boost perceived efficiency, they are not of equal importance. This study's results show that the service environment has the single strongest impact on perceived efficiency. This

provides clear instruction for resource allocation: managers should prioritize investments in tangible environmental factors. For instance, customers rated having ‘up-to-date facilities’ highly. This implies that ensuring a modern and well-organized layout with clear navigation paths for robots is not merely an aesthetic choice but the most effective investment for enhancing customer perceptions of robot efficiency. Likewise, personalization was the second most influential factor, followed by service authenticity. This finding suggests that restaurant managers should ensure that the robots which they deploy can adapt to individual customer needs and adjust if/when these needs change. For example, robots should remember the history of customer orders and/or their food intolerances but inquire if these factors remain unchanged when the customer returns after a pro-longed break. Likewise, restaurant managers should prioritize the design of robot interactions conveying a sense of authenticity, such as by using natural language in communications to foster positive customer experiences. Creating a conducive service environment, with clear navigation paths for robots, is also key to ensuring smooth and efficient robot operations, thus prompting positive customer feedback on robotic service efficiency. However, deploying service robots should not be viewed as universally suitable but rather depends on the context. For restaurants seeking to improve operational efficiency and provide innovative services, particularly in fast-casual or technology-driven dining styles, robotic services can enhance the guest experience (Qiu et al., 2020). However, in restaurants such as fine dining or family-oriented establishments, where social prestige or sophisticated interaction is key, robots may not meet customer expectations. Therefore, the decision to adopt service robots should be guided by the restaurant’s positioning, customer segment, and ability to design service encounters that generate functional and epistemic value.

Second, the study identifies the two primary channels through which restaurateurs can create a positive impression of efficiency: functional value and epistemic value. The mediation analysis

revealed that these two dimensions were the only significant pathways linking the service elements to perceived efficiency. This suggests a dual strategy for service design. First, managers should emphasize the robot's practical utility (i.e., functional value), as customers value tasks that enhance their dining experience and reduce waiting times. At the same time, they must leverage the novelty of technology (i.e., epistemic value), as customers tend to gain higher satisfaction from curiosity and new experiences. Therefore, deploying robots for visibly practical roles while also programming them with unique, engaging features is the most effective way to improve efficiency perceptions. Importantly, the results caution against positioning a robotic restaurant as a place for social prestige as social value items scoring low. This suggests that marketing of robotic restaurants should focus on convenience and novel entertainment rather than social status.

The study's findings on the influence of socio-demographic variables emphasize the need for restaurant managers to deploy targeted robotic service. Managers should tailor their robot service design to the specific needs and preferences of different customer segments. More specifically, middle-aged customers may appreciate robots that provide quick service, while parents with children may prioritize robots offering engaging interactions for younger consumers. When targeting these customer groups, managers should deploy and train robots which excel in these tasks. Likewise, higher-income individuals may be more receptive to robots in upscale settings, expecting a sophisticated technological experience exemplified by seamless order delivery and outstanding politeness. Managers should invest in robots that can deliver on these consumer expectations, thus increasing the probability of their positive evaluation. Ultimately, by understanding the diverse needs of their customers, managers can optimize the deployment of service robots to maximize/optimize customer satisfaction.

6. Limitations and future research

One of the limitations that needs to be acknowledged is the sample size of 155 participants. Although it is sufficient for the statistical methods used, the generalizability of the results is restricted. Future research should aim to replicate the findings with larger and diverse groups to improve external validity. Furthermore, although the sample includes participants from Japan, Singapore, and the United States to offer perspectives from diverse culturally and technologically advanced markets, these participants may not fully represent consumers in other geographic regions, where attitudes toward service robots and levels of technological adoption may differ substantially. Cultural norms, service expectations, and familiarity with automation are likely to influence perceptions of robotic efficiency. Therefore, future studies should include cross-cultural comparisons to explore how contextual factors impact the evaluation of service robots.

This study relies on a sample of customers who self-reported their prior experience of dining in robotic restaurants. While this approach allows access to a relevant and otherwise hard-to-reach population, it may be subject to recall bias and self-selection effects. Future research would benefit from field-based data collection, such as surveying customers of operational robotic restaurants during or immediately following their dining experience, thereby capturing perceptions in real time and enhancing the ecological validity of the findings.

This study focused specifically on personalization, authenticity, and the service environment as key antecedents of perceived efficiency in robotic service encounters. While these factors capture core elements of the customer–robot interaction, other variables may also exert significant influence on efficiency perceptions. For example, perceived enjoyment reflects the intrinsic pleasure derived from interacting with a technology and has been shown to enhance customers' responses such as satisfaction and intention to use (Huang et al., 2024). Likewise,

perceived risk, i.e., concerns related to privacy, and security (Karwatzki et al., 2022), may undermine users' confidence and reduce perceived efficiency. Therefore, future research should broaden the conceptual model to incorporate additional psychological and affective factors, which could yield a more holistic understanding of the determinants of perceived efficiency and deepen theoretical insights into the mechanisms driving customer responses to service robots.

Lastly, this study focused on four key dimensions of perceived value, including emotional, social, functional, and epistemic value. Additional value facets may be relevant in specific restaurant contexts. For example, value for money may be particularly salient in fast food establishments, where cost-efficiency and perceived affordability strongly influence customer perceptions. Future research should therefore broaden the scope of perceived value to include these additional dimensions and examine how their relative importance varies across diverse restaurant types that deploy service robots, thereby providing a more nuanced understanding of how value perceptions shape customer experiences in technology-mediated dining settings.

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