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Are We Prepared for the Rise of Service Robots? – A Review on Acceptance Models

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ABSTRACT

Due to demographic change, technological innovations are needed to maintain standards of care. In addition, other service sectors face staffing challenges. Service robots are one technology that can address these challenges in this volatile, uncertain, complex, and ambiguous (VUCA) world. Since acceptance is necessary for the future success of these technologies, this literature review provides an overview on existing acceptance models for service robots. The identified models are structured using a robot classification to identify which domains are currently covered.

Keywords: Service robot, Acceptance measurement, Literature review, Technology acceptance model

INTRODUCTION

The challenge of demographic change in conjunction with a declining number of caregivers is well known (World Health Organization, 2015). To ensure individualized care for seniors, researchers are working on the development of digital devices to support caregivers in their daily tasks. The Covid-19 pandemic, in particular, emphasized this need for flexible services. In this context, service robots, i.e. physical robots that perform tasks to assist humans outside of industrial environments (International Organization for Standardization, 2012), can not only address this challenge but also support various professional fields such as education (Savela et al., 2018).

Regardless of their scope, their use and benefits are highly dependent on user acceptance, which is defined as actual use of the technology (Davis, 1989). Although, many studies have been conducted, they are difficult to compare due to different study designs, making it difficult to build upon them (Savela et al., 2018). This is the case because traditional acceptance models such as Davis' Technology Acceptance Model (TAM) (1989), are not considered sufficient for the interaction-oriented technology of robots (Heerink et al., 2010). Therefore, various acceptance models that focus on service robots have been developed. As a result, it is difficult and time-consuming for researchers to determine the most appropriate model to identify the factors that influence the acceptance of the service robots they developed (Jung et al., 2021). To analyse the acceptance of new developments of service robots in this rapidly evolving research field, an overview of existing models as well as their potential application is necessary.

The aim of this research is to assist researchers and developers by providing an overview of existing models for measuring the acceptance of service robots. To achieve this goal, the following main research question is proposed: *Which models currently exist to measure the acceptance of different service robots?*

Therefore, the paper is organized as follows. First, the topic of acceptance measurement is briefly outlined, followed by the methodological approach of the study. Subsequently, the results of the study are presented and concluded with a short discussion.

MODELS TO UNDERSTAND REASONS FOR TECHNOLOGY ACCEPTANCE

Davis developed the first acceptance model to evaluate the acceptance of computers (Davis, 1989). It is based on the theory of reasoned action (TRA) (Fishbein and Ajzen, 1975) and correlated the constructs perceived usefulness (PU) and perceived ease of use (E) as influencing factor for behavioral intention (BI). BI is the influencing factor for the actual use (U) of the technology (Davis, 1989). Most subsequent models (e.g. TAM 3 (Venkatesh and Bala, 2008)) are based on these correlations and therefore rely on the assumption that those are reliable and correct (Benbasat and Barki, 2007). Venkatesh et al. (2003) reviewed and compared eight models that have been developed since the original TAM and derived the unified theory of acceptance and use of technology (UTAUT). It is more detailed and uses performance expectancy (PE), effort expectancy (EE) and social influence (SI) as factors for BI. BI and facilitating conditions (FC) are then influencing factors for U. In addition, the moderator variables gender, age, experience, and voluntariness of use are added (Venkatesh et al., 2003).

Since the development of these most well-known models, other models have been developed for specific technologies or target groups, such as the Senior Technology Acceptance Model (STAM) (Chen and Chan, 2014). The acceptance models on service robots are reviewed in this study. However, previous literature reviews on service robot acceptance focused on acceptance variables (Graaf and Ben Allouch, 2013), acceptability questionnaires (Krägeloh et al., 2019), acceptance factors of older adults, people with dementia or cognitive impairment (Whelan et al., 2018), social psychology implications (J. Young et al., 2009), and evaluation methodologies (Jung et al., 2021).

Methodology

Following Cooper's (1988) taxonomy for literature reviews, the focus of this review is on existing research methods and practices. The goal is to integrate these into a matrix to identify key issues for researchers and practitioners in service robotics from a neutral perspective (Cooper, 1988). The research follows the guidelines of Brocke et al. (2009), including a concept-centric approach by Webster and Watson (2002) for literature analysis and synthesis.

The basis is a search based on the search string robot* AND accept* AND (measur* OR method* OR model* OR evaluation*), which was used for

Scopus, Science Direct, IEEE Xplore, as well as Google Scholar. When possible, robot* and accept* was used for title only, as it is assumed that the development of an acceptance model for robots is reflected in the title. The search was conducted in early February 2022 and included all research papers available up to January 2022.

Of the 274 research papers identified, duplicates and non-English language papers were excluded, resulting in 226 unique research papers. These were screened based on their title. Consequently, further 67 articles that had a different focus e.g., on industrial or surgical robots, or were unrelated, were removed from the study. Reading the abstracts of the remaining articles further reduced the sample, e.g., in case the definitions of service robots or acceptance used for this study were not met. Finally, the 15 identified acceptance models for service robots were related to the robot classification and application role of Onnasch et al. (2020).

ACCEPTANCE MODELS FOR SERVICE ROBOTS

The research by Onnasch and Roesler (2020) provides a taxonomy for structuring and analyzing human-robot interaction. For this study, we use the context (field of application, exposure) and robot classification (task specification, morphology, degree of autonomy) contained therein, as it allows us to categorize each scenario and robot (Onnasch and Roesler, 2020). However, degree of autonomy was omitted, since no researcher explicitly stated that a particular level of robot autonomy is required or present. Exposure was also omitted because all models were generally expected to work for physical robots in the field, although sometimes only laboratory testing was possible. Industry was excluded from the field of application because it is excluded by the definition of service robot. Morphology was simplified, as there were no differences between appearance, communication, movement, and context.

With the exception of two models (Go et al., 2020; Wirtz et al., 2018), all models were not only created theoretically but also tested in an experiment. The information on the experiments or the description of the two previous mentioned models were used for the analysis, which is presented in Table 1. The identified models are briefly presented below, categorized by their focus on service robots in general and social robots, which are a subgroup of service robots.

Seven models were identified that focus on service robots in different application areas. Park and Del Pobil (2012) proposed a model for service robot acceptance. However, since it was tested within a questionnaire with 1,014 worldwide participants who had general experience with service robots, it is not known for which type of service robot the model really works (PARK and DEL POBIL, 2012). Wirtz et al. (2018) proposed a model for customer acceptance of service robots (sRAM) (Wirtz et al., 2018), which Fuentes-Moraleda et al. (2020) built upon to make it useful for hotel-specific service robots. They used existing online hotel rating data to test their model (Fuentes-Moraleda et al., 2020). Due to the nature of the analysis and although robot names are provided, it is not known exactly in what context the robots were used in the hotels. Zhong et al. (2020) proposes another

Table 1. Service robot acceptance models related to robot classification and field of application (Onnasch and Roesler, 2020) ordered by publication year.

Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Name		Almere				SFRAM	sRAM		hotel-specific sRAM	PRAM	iTAM	HANCON	RAM-care		
Robot type		social assistive	social interactive	service	teaching	frontline service	service	social	service	persuasive	advanced	telepresence	care	service	social
Focus Group		Seniors	General	General	Teachers	General	Customer	Domestic	Hotel Guests	General	General	Students	Healthcare Professionals	Consumer	Costumer
Categories \ Authors		Heerink et al., 2010	Shin & Choo, 2011	Park & De Pobil, 2012	Park & Kwon, 2016	Stock & Merkle, 2017	Wirtz et al., 2018	Graaf et al., 2019	Fuentes Moraleda et al., 2020	Ghazali et al., 2020	Go et al., 2020	Han & Conti, 2020	Turja et al., 2020	Zhong et al., 2020	Subero-Naneva et al., 2022
Field of Application	service	x	x	x		x	x	x	x		x		x	x	x
	military & police														
	space expedition														
	therapy	x											x		
	education				x	x						x			
	entertainment	x	x		x	x	x	x	x	x	x		x	x	
	none									x					
Robot Task Specification	information exchange	x	x		x	x	x	x	x	x	x	x	x	x	x
	precision														
	physical load reduction												x		
	transport					x			x	x	x			x	
	manipulation							x							
	cognitive stimulation				x	x				x		x			
	emotional stimulation	x	x		x	x	x	x	x	x	x		x	x	
	physical stimulation												x		
Robot Morphology	anthropomorphic		x		x	x	x			x	x		x		x
	zoomorphic	x	x		x								x		
	technical	x			x		x				x	x	x		

model for hotel service robots. It is evaluated based on surveys of hotel visitors from different hotels, but the robots used are not mentioned (Zhong et al., 2020). The social frontline robot acceptance model (SFRAM) focuses on frontline service robots that f.e. help at an information desk (Stock and Merkle, 2017). The RAM-care model focuses on the use of robots by care professionals (Turja et al., 2020). Thus, it is the only model that focuses on employees. Go et al. (2020) proposed the interactive technology acceptance model (iTAM) for advanced robotics, i.e., "[…] artificial intelligence (AI) robots equipped with machine learning applications […]" (Go et al., 2020).

Seven models focus on the subset of social robots, that act in socially accepted ways based on their role in an interaction (Duffy, 2003; Terrence Fong et al., 2003). Heerinks' Almere model is one of the most well-known models for social robots and focuses on social assistive robots for seniors

(Heerink et al., 2010). Shin and Choo (2011) proposed a general model for socially interactive robots, and de Graaf et al. (2019) one with focus on social robots in domestic homes. Ghazali et al. (2020) created a model to study the acceptance of persuasive robots (PRAM), a subset of social robots. Park et al. (2016) developed a model for using social robots as teaching assistants. Han and Conti (2020) proposed the HANCON model for educational settings with telepresence robots. Subero-Navarro et al. (2022) proposed a model to study customer acceptance of social robots retail.

Table 1 shows that most models cover both services, such as cleaning, and entertainment, such as playing games, as application domains. Consequently, information exchange and emotional stimulation required for these application domains are the most prominent fields for tasks specification. For application domains such as military and police and space expedition, there is no research on acceptance models. Although therapy is in general a frequently researched topic (Savela et al., 2018), specific therapy-oriented models are rare. Precision, physical load reduction and physical stimulation tasks are scarce in models. All types of morphology are already tested in the models.

Seven models are based on TAM (Davis, 1989; Ghazali et al., 2020; Go et al., 2020; PARK and DEL POBIL, 2012; PARK and Kwon, 2016; Stock and Merkle, 2017; Wirtz et al., 2018; Zhong et al., 2020), four on UTAUT (Han and Conti, 2020; Heerink et al., 2010; Shin and Choo, 2011; Venkatesh et al., 2003), and RAM-care builds on Almere (Heerink et al., 2010; Turja et al., 2020). Some added other models and theories in addition to the self-identified measures. For example, SFRAM added role theory (Solomon et al., 1985; Stock and Merkle, 2017), PRAM uses the construct "enjoy" from TAM 3 (Ghazali et al., 2020; Venkatesh and Bala, 2008), and HANCON uses the Post Acceptance Model (PAM) (Bhattacherjee, 2001; Han and Conti, 2020). Graaf et al.'s (2019) and Subero-Naneva et al.'s (2022) models are the only ones that are not based on a TAM-related theory. Graaf's is based on the theory of planned behavior (TPB), which is an extension of TRA (Ajzen, 1991; Graaf et al., 2019). The Subero-Naneva et al. model is based on the Cognitive-Affective-Normative (CAN) model (Subero-Navarro et al., 2022). Since UTAUT is based on TAM, among others, it can be inferred that most models depend on TAM.

Discussion and Further Research

This paper gives an overview of existing acceptance models for service robots, on which models they are based and for which application fields as well as robot types they can be used. Consequently, it provides researchers and developers with a starting point for analyzing the acceptance of the robots, which they develop. However, it is important to keep in mind that the influencing constructs may be different when evaluating a different type of robot (Graaf et al., 2019). Although the study takes a specific approach, some points need to be discussed and further research is needed.

The number of identified research papers and models highlights the importance of the topic. However, it also makes it difficult to draw general conclusions. Consequently, it is difficult to analyze the acceptance of service robots, but also to use the existing knowledge for new robot developments. Further research should concentrate on a qualitative analysis of the initial findings presented within this paper.

It should be noted that the matrix in Table 1 represents only the use cases for which the models were tested by the authors and the information available in the first publication of the model. The transferability of the models to other use cases is not generalizable (Graaf et al., 2019), but it cannot be ruled out either. In addition, researchers have not clearly mentioned all properties of the robots that can be assessed with their models. Therefore, it is possible that the results of the paper draw different conclusions than intended by the authors. Future research should include studies that tested the models in different use cases.

Finally, many studies of service robot acceptance have used existing models and added certain constructs, but without claiming to develop a new model. Therefore, some developments that could nevertheless function as a new model have not been included in this study. Consequently, a qualitative analysis on all possible constructs relevant for the acceptance of service robots would be useful.

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