Measuring Intention to Use in HRI - A Parsimonious Model

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***Abstract*—One of the main limitations in current social robotics research is to find commonly accepted measures that allow to compare and benchmark different approaches. In this work, we present a parsimonious adaptation of the Almere model consisting of four antecedent factors of intention to use (Perceived Usefulness, Perceived Ease of Use, Perceived Entertainment and Social Influence). The proposal is validated in a pilot study with N=219 participants.**

***Index Terms*—Technology Acceptance Model, Service robots, Human-Robot Interaction**

I. Introduction

The ultimate goal of service robotics is to create memorable experiences [1] and not only solve customer requests (e.g., helping them complete a transfer with an ATM). In order to achieve such an ambitious goal, robots need to be endowed with social skills and be capable of communicating through multi-modal channels in an easy and intuitive way [2]. However, service organisations are using two profiles of robots: some with a mechanical design (e.g., Roomba) to perform backroom tasks (e.g., room cleaning service), and others with more anthropomorphic designs (e.g., Pepper) for front-office tasks where direct customer contact is required (e.g., hospital receptionist) [1]. It is these latter designs that are posing the greatest challenge to both designers and service organisations. Thus, service robotics share, to some extent, some of the objectives of social robotics. Some companies have failed in equipping their facilities with service robots, such as the Henn-na hotel in Japan, due to numerous failures and errors in service delivery [3]. These problems have arisen from a lack of understanding between robot designers, who do not understand market needs, and business managers, who are unaware of the reality of robots and misinterpret their limited functions as failures [4].

Technology acceptance models are used to evaluate the results of first Human-Robot Interaction (HRI) experiences and to estimate the intention to continue using robots [5], technology acceptance models are used [5]. Savela et al. [6] review the models used in HRI, the pioneer being the so-called Almere model [7]. However, this pioneering model, consisting of six direct and four indirect precedents, is difficult to replicate in such a nascent market. In fact, a decade later Ghazali et al. [8] proposed using a simpler model and adapted the Technology Acceptance Model to mitigate some of these difficulties seeing how difficult it was to replicate such a complex model with an audience so novice in dealing with robots, proposed using a simpler model and adapted the Technology Acceptance Model. Another problem arises from the use of Wizard of Oz scenarios. These scenarios, as well as descriptions of robot abilities in text, pictures or videos, have been criticised because they convey the impression that Artificial Intelligent systems have reached degrees of sophistication that are far removed from reality, generating false perceptions about their real abilities [6].

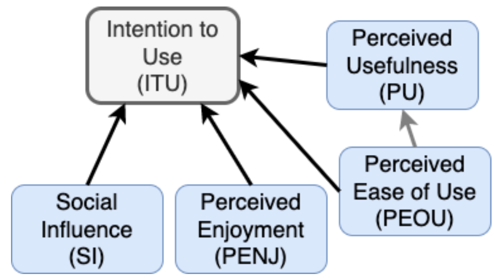

Fig. 1. General structural model. Black arrows show antecedents, while the grey arrow shows a mediating role.

II. Proposed Model of Intention to Use

This work proposes a parsimonious adaptation of Almere's model consisting of four antecedent factors of intention to use (see Perceived Usefulness, Perceived Ease of Use, Perceived Entertainment and Social Influence in Fig. 1). Perceived Usefulness has a mediating role between Perceived Ease of Use and Intention to Use. There are several reasons for proposing a different approach:

- According to cognitive psychology's principles, although first impressions help to form a general idea about novelties, it is not sufficient to appreciate the relevant factors that characterise them. Therefore, it is preferable to consider simple models to assess first experiences than to consider complex models about relationships that they have not had sufficient time to appreciate and internalise [9].
- The literature on modelling technological acceptance of devices derived from new technologies (e.g., computers, smartphones, etc.) proposes using simple models in novel

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	Factor loading	T	M	SD
Perceived Enjoyment (AVE: 0.66; CR: 0.82; Alpha: 0.82)				
It's fun to talk to the robot	0.81	3.61	3.1	1.31
It's fun to play with the robot	0.88	3.62	3.56	1.21
The robot looks enjoyable	0.66	3.58	2.91	1.32
Perceived ease of use (AVE: 0.60; CR: 0.78; Alpha: 0.77)				
Immediately I learned how to use the robot	0.83	4.83	3.93	1.14
The robot seemed easy to use	0.81	4.47	4.1	1.06
I think I can use the robot without any help	0.71	4.53	3.71	1.19
Perceived usefulness (AVE: 0.65; CR: 0.82; Alpha: 0.82)				
I think the robot is useful to entertain	0.68	6.97	3.87	1.24
It would be nice to have the robot to entertain	0.85	7.96	3.09	1.25
I think the robot could be used to entertain me and do other things	0.81	7.38	3.38	1.21
Social influence (AVE: 0.70; CR: 0.85; Alpha: 0.85)				
I think my friends would like me to use the robot	0.74	11.96	2.96	1.20
I think it would give a good impression if I played with the robot	0.90	20.83	2.9	1.19
People whom I value your opinion I think they would look good that I play with the robot	0.78	15.63	3.12	1.22
Intention to use (AVE: 0.67; CR: 0.83; Alpha: 0.82)				
If the robot was available I would try to use it	0.71	3.52	3.37	1.15
If the robot was available I would try to use it whenever I could in my spare time	0.88	3.70	2.74	1.22
If the robot was available I would be thinking sometimes when using it	0.77	3.55	2.18	1.15

TABLE I

NOTE: THE MODEL FITS CHI-SQUARE (χ^2)=82.6673; DF=74; P=0.22943; RMSEA=0.023; CFI=0.995; NNFI=0.992, AVE IS THE AVERAGE VARIANCE EXTRACTED, CR IS THE COMPOSITE RELIABILITY.

	PENJ	PEOU	PU	SI	ITU
PENJ	0.82				
PEOU	0.40**	0.82			
PU	0.62***	0.35**	0.81		
SI	0.67***	0.11 (ns)	0.67***	0.83	
ITU	0.64***	0.11 (ns)	0.61***	0.64***	0.82

TABLE II

DISCRIMINANT VALIDITY OF THE SCALES. BELOW THE DIAGONAL THE CORRELATION ESTIMATED BETWEEN THE FACTORS (NS DENOTES NO SIGNIFICANCE, * DENOTES .01 $<p<$.05, ** DENOTES .001 $<p<$.01, AND *** DENOTES $p<$.001)

- markets (TAM-derived) and, as experience and familiarity with consumption of these devices increases, proposing more complex models (UTAUT-derived such as Almere) [5], [10].
- UTAUT-derived models (such as Almere) require large sample sizes that are difficult to achieve in robot experiments, as was noticed by Ghazali et al. when proposed a TAM-derived model [8].
- The trust factor is still debated in the literature [5], [8].
- The Attitude factor, proposed in the Almere model, has theoretical inconsistency (it considers attitude and its antecedents, perceived usefulness and ease of use, in parallel).

Therefore, in the model we present, trust and attitude have been discarded. Moreover, we considered that the characteristics of service delivery should have at least one factor from each element that makes up them (functional, socio-emotional, and relational) [1]. Based on these precedents, no indirect factors have been considered in the proposed model.

With all these changes, a model consisting of four direct antecedents and one mediating antecedent has been proposed. Our model establishes the following hypotheses (see Fig. 1):

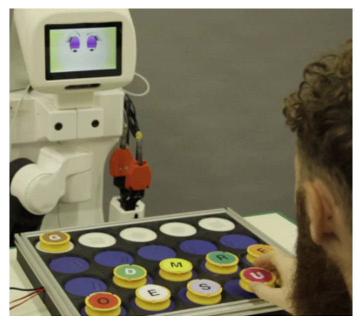

Fig. 2. A participant plays the Nobel Prize Winner game with the assistance of the robot.

H1. PU is positively related to ITU
H2. PEOU is positively related to PU
H3. PEOU is positively related to ITU
H4. PENJ is positively related to ITU
H5. SI is positively related to ITU

III. MODEL VALIDATION AND DISCUSSION

To test and validate the proposed model, an experiment was conducted at an international fair with N=219 participants. The experiment is fully described in [5], we reproduce here the essential details for the discussion.

We designed an assistive task, which consists of guessing the name of a Nobel Prize Winner using the tokens available on a board (see Fig. 2). As there was only a single solution, the task was hard enough to require the assistance of a robot. Thus, a TIAGo robot was delivered different degrees of assistance using multi-modal communication in an autonomous fashion to assist participants in completing the game. Once they had lived the experience, they filled in a questionnaire consisting of five constructs and fifteen items that they had to evaluate on a five-point Likert scale (1 = "strongly disagree" and 5 = "strongly agree"). The constructs were: Intention to use: "If the robot was available, I would try to use it", "..., I would try to use it whenever I could in my spare time", "..., I would sometimes think about using it". **Perceived Usefulness**: "I think the robot is useful to entertain", "It would be nice to have the robot to entertain", "I think the robot could be used to entertain me and do other things". **Perceived Ease of Use**: "Immediately I learned how to use the robot", "The robot seemed easy to use", "I think I can use the robot without any help". **Perceived Enjoyment**: "It's fun to talk to the robot", "It's fun to play with the robot", "The robot looks enjoyable". **Social Influence**: "I think my friends would like me to use the robot", "I think it would give a good impression if I played with the robot", "People whom I value your opinion I think they would look good that I play with the robot" [5], [7].

Once the data were collected, the psychometric properties of the constructs were assessed and the model was estimated by structural equation model, based on variance and covariance matrices by maximum likelihood with EQS 6.4. However, since the model is very simple it is possible to fit it by ordinary least squares by adjusting the equations:

$$ITU = \alpha + \beta_1 PU + \beta_2 PEOU + \beta_3 PENJ + \beta_4 SI + e_i \quad (1)$$

$$PU = \alpha + \delta_1 PEOU + e_i \quad (2)$$

where α is the intercept of the model, β and δ are the explanatory variables of the model and finally e is the random error with expectation 0 and variance σ^2.

The psychometric characteristics of each item were analysed with respect to its scale (latent variables), resulting in the removal of four items. Table I describes the weight achieved by each item (its correlation with respect to its scale), the composite reliability (CR) and convergent validity of the scales used (AVE) and, in addition, Cronbach's α coefficient was used as an index of scales reliability. In addition, Table II shows the discriminant validity of the scales, where the square root of the AVE of each scale is higher than the correlations with the rest of the scales, i.e. none of the values below the diagonal of the matrix reaches the values on the diagonal (Fornell and Larcker test) [11]. The relationship model was then estimated using SEM.

The SEM adjustment for intention to use reached an R^2 of 0.90, and 0.11 for perceived usefulness (Table III). In addition, the results confirm the five proposed hypotheses: the Intention to use a robot that delivers a service is mainly explained by Social influence (β=0.45) and Perceived enjoyment (β=0.31), and, to a lesser extent, by Perceived usefulness (β=0.25) and perceived Ease of use (β=0.12). In turn, Perceived usefulness is explained by Perceived ease of use (β=0.33).

Compared to Almere's model [7], where the partial models range from 0.49 to 0.79 and the R^2 of the overall model is not provided, the fit is much better and the significant factors are practically the same. However, Almere's model gives higher values to the functional elements (Perceived usefulness and Perceived ease of use), while in this estimation the values that achieve the highest weight are the socio-emotional and relational factors, as is usual in the delivery of services that generates memorable experience [1].

Independent variable	Dependent variable	Beta	T	$\mathbf{R^2}$	Beta Almere
PU	ITU	0.25*	2.05	0.90	0.46**
PEOU		0.12*	2.21		0.28**
PENJ		0.31***	4.73		0.13*
SI		0.45***	4.23		0.17*
PEOU	PU	0.33***	3.63	0.11	0.49**

TABLE III
CAUSAL RELATIONS. OUR MODEL (BETA) VS ALMERE'S MODEL (BETA ALMERE) (* DENOTES .01 $<p<$.05, ** DENOTES .001 $<p<$.01, AND *** DENOTES $p<$.001).

IV. CONCLUSIONS AND FUTURE WORK

This paper has presented a simple model for estimating the intention to use social robots by customers in a front-office service delivery context, which includes factors from each of the essential elements of the service: functional, socio-emotional and relational. The findings achieved in this study, after a sample of potential customers received live service delivery by a social robot, show that social influence and entertainment are more important than usefulness and ease of use in the intention to continue using this service. The results are in line with those expected if the service had been provided by a human employee [11]. Noting that, in a customer service context where customer interaction should be prioritised, humanoid designs with the ability to communicate seem more appropriate, while for backroom contexts, mechanoid designs could be considered. On the other hand, there does not seem to be an optimal social robot design [12], but rather the context in which the service is to be provided (front-office, backroom, services of a hedonic or utilitarian nature), as well as the individual characteristics of the customers (gender, personality traits, attitude towards new technologies, etc.) will determine the specific characteristics of the design [11], while the use or design of multitasking robots is not possible [5]. Different lines of future research are also derived from the results. Firstly, a robot has been tested that gave advice to customers to complete the task, but did not perform the task itself. Therefore, one can also study the technological acceptance of robots that do the task themselves, including what happens if they make mistakes, one of the hottest topics in the literature [13]. Secondly, it should also be noted that the introduction of social robots in service organisations also represents a major challenge to gain the acceptance of front-office employees [14]. Therefore, the model can also be used to estimate the technological acceptance of employees.

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