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ACCEPTANCE OF INDUSTRIAL COLLABORATIVE ROBOTS: PRELIMINAR RESULTS OF APPLICATION OF PORTUGUESE VERSION OF THE FRANKENSTEIN SYNDROME QUESTIONNAIRE (FSQ)

Ana Pinto[1], Mariana Ferraz[2] , Tatsuya Nomura[3], Joana Santos[2,4]
[1]University of Coimbra, Centre for Business and Economics Research (CEBER), Faculty of Sciences and Technology; luisa.s.pinto@gmail.com; ORCID 0000-0002-8280-9887
[2]Center for Translational Health and Medical Biotechnology Research (TBIO), School of Health (ESS), Polytechnic of Porto; jds@ess.ipp.pt; ORCID 0000-0002-2777-3244; maft@ess.ipp.pt; ORCID 0009-0002-0105-7669
[3]Department of Media Information, Faculty of Science and Technologym Ryukoku University, Japan; nomura@rins.ryukoku.ac.jp; ORCID0000-0002-4391-9792
[4]Faculty of Engineering, Institute of Science and Innovation in Mechanical and Industrial Engineering, University of Porto; jds@ess.ipp.pt; ORCID 0000-0002-2777-3244

Abstract
Background: Cobots are highly flexible and able to operate in the same workspace and at the same time with the worker. The use of these technologies allows for increased production performance while ensuring comfort and confidence for the worker. Robot acceptance is still a controversial topic with various approaches and methods to measure acceptance of humanoid robots. **Objective:** This study aimed to evaluate cobots acceptance after a motor assembly task in a collaborative workstation. **Methods:** 30 university students were divided into two groups, with group 1 having read the assembly instructions before the usage of the assembly workstation and group 2 without having any previous knowledge about the car engine. All participants completed the Portuguese version of the Frankenstein Syndrome Questionnaire (FSQ). Data analyses were carried out using descriptive and inferential statistics using IBM SPSS Statistics software, version 28.0. **Results:** One correlations was found between the scales of the FSQ ($p < 0.05$). **Conclusion:** It was possible to conclude that the acceptance of robots by the participants in group 1 and group 2 was the same. **Application:** This study can contribute to understanding which factors explain the acceptance of collaborative robots, to improve human-robot interaction.

Keywords: Human-Robot Collaboration, Cobot, Industry 5.0, Technology Acceptance

Introduction

With technological changes that have been occurring, new machines, new sources, and forms of organizing work have emerged, making organizations more efficient and productive (Groumpos, 2021). Industry 5.0 that highlighting the importance of collaboration between humans and robots, creating a human-focused work environment (Doyle-Kent & Kopacek, 2021). The use of industrial robots in production systems to increase productivity is not new. For many decades, industrial robots and humans worked separately on production lines. However, with the changing customer demands, manufacturing companies face a challenge to answer to a large volume of products. This requires more flexible production systems, without sacrificing efficiency and productivity. To face this challenge, it was necessary to explore new forms of cooperation and collaboration between humans and robots (Fernández et al., 2017; Liu & Wang, 2017). As a result, collaborative robots, known as cobots, emerged.

Human-Robot Collaboration (HRC)

The introduction of a collaborative workplace, aims to improve working conditions and, at the same time, to increase production performance. This can be particularly interesting regarding a collaborative assembly station, which is one of the most attractive and discussed applications of HRC in the industry (Gualtieri, Rauch, et al., 2020). During a HRC, the human's reaction isn't only influenced by the robot's appearance, but also by its movements, including trajectory, speed, and reach. For an ideal interaction between man and machine, it's important to consider how these parameters are organized to make the robot's movement similar to a human's movement (Abel et al., 2020).

With the increasing sophistication of these machines, it's possible for them to take on more complex and challenging tasks that were previously reserved exclusively for humans. However, it's important to remember that, although cobots can offer many benefits and increase efficiency in various areas, they continue to be programmed by humans. Therefore, it's essential to ensure that their use is ethical and responsible. In this context, for a collaborative station to be successful, it's fundamental to advance in terms of comfort and trust, which can consequently contribute to greater acceptance of cobots in different activities (Krägeloh et al., 2019).

Acceptance and Acceptability

Conventional industrial robots are automated systems that function efficiently, without considering human comfort. On the other hand, humanoid robot systems are more predictable for workers, allowing them to trust these technologies (Kuz et al., 2013). Acceptance of the cobot as a coworker is important for workers to trust the system and accept it. Humans have the ability to modify and improve tools and technologies over generations. However, some tools are gradually replaced by others, leading to the critical question of why a tool is adopted or rejected by users. At the time of adopting a piece of equipment or machine, it's important to distinguish between two concepts, acceptability and acceptance. Acceptability is defined as *a priori* phenomenon, consisting of an explicit willingness to use a machine, i.e., it's a mental representation, more or less positive, that the user has before using the machine. On the other hand, acceptance is seen as a pragmatic evaluation *a posteriori*, implying a use by the user before their evaluation of acceptance (Alexandre et al., 2018). In practice, when a worker is confronted with a cobot at a workplace, they first evaluate the acceptability, and after using the tool, acceptance is built.

Over the years, various approaches have been developed regarding technology acceptance. The first approach to emerge was developed by psycho-ergonomics, which focuses on ergonomic criteria (usability and accessibility) that determine machine acceptance. Social psychology can also be considered a practical application for technology acceptance, in which the worker is seen as a social agent. The worker's profile is described as a fundamental criterion for acceptance, as distinct characteristics can reveal a greater or lesser inclination for technology acceptance (Alexandre et al., 2018).

Through the combination of ergonomic and social approaches, a user and productivity-centered approach emerged in the 1980s. The Technology Acceptance Model (TAM) was created to predict worker behavior regarding technology acceptance. The main factors influencing technology acceptance are Perceived Usefulness (PU) and Perceived Ease Of Use (PEOU). PU is defined as the belief that the technology will improve work performance, while PEOU is the belief that the technology is easy to use (Alexandre et al., 2018). Over the years, the TAM has evolved, and various authors have added new criteria that contribute to PU and PEOU, such as the influence of support, motivation, machine responsiveness, visibility, and individual experience. Venkatesh and Davis (2000) developed the second version of the TAM, TAM 2, which added social influence and four instrumental processes for PU and PEOU. These processes contain task relevance, outcome quality, result demonstration, and experience criterion. This new version also takes into account worker attitude, behavioral intention, actual system use, and external variables (individuals and organizational contexts).

The existing literature on acceptance highlights another interesting approach that involves the user experience with a certain machine or tool. When talking about user experience, various criteria can be used, such as utility, usability, value, desire, location, credibility, and accessibility, which are evaluated holistically to determine the value of the machine/tool (Alexandre et al., 2018).

However, some authors have suggested that creating a specific theoretical model was not mandatory to evaluate the user experience. Thus, criteria emerge that include aesthetic considerations, emotional design, trust in the machine, user profile (age, education, gender, cognitive characteristics, and competencies), attitude towards technology, cognitive load, and the quality and complexity of the information (Alexandre et al., 2018).

Methods for measuring acceptance

The existing literature on methods to measure robot acceptance highlights six methods, which will be briefly described below.

The Negative Attitudes toward Robots Scale (NARS) was originally developed in Japanese and consists of a five-point Likert scale, ranging from "strongly disagree" to "strongly agree". This questionnaire was based on a theoretical model and on questionnaires that assessed apprehension of communication and anxiety regarding computers (Nomura et al., 2006).

The Robotic Social Attributes Scale (RoSAS) is a questionnaire developed to assess perceived attributes in robots and how they affect humans in interaction with robots. It arose from a combination of items from the Godspeed questionnaire and a review of the literature on social cognition. It consists of eighteen items divided into three subscales: warmth, competence, and discomfort (Carpinella et al., 2017).

The Ethical Acceptability Scale was created by a team of experts in ethics, psychology, therapy, and engineering, with the aim of assessing ethical issues related to the use of robots in therapy for children with autism. The questionnaire has twelve items, which are evaluated on a five-point Likert scale. Through studies developed with this questionnaire, it was concluded that the scale can be divided into three subscales: ethical acceptability for use, ethical acceptability of humanoid interaction, and ethical acceptability of non-human appearance (Peca et al., 2016).

The Technology-Specific Expectations Scale (TSES) emerged to assess users' expectations before interacting with a robot. The underlying theoretical basis for this scale is the Theory of Confirmation of Expectations, which states that consumer satisfaction is influenced by the confirmation of their initial expectations. This scale contains ten questions on a five-point Likert scale, which are divided into two subscales: capabilities and fictional vision (Krägeloh et al., 2019).

The creators of the Multi-Dimensional Robot Attitude Scale observed that previous scales only focused on negative attitudes towards robots. Therefore, they found it necessary to create a measure that involved a wider range of attitudinal aspects. As a result, 125 items were developed and evaluated on a seven-point Likert scale ranging from -3 (not at all) to 3 (very much) (Krägeloh et al., 2019).

Since the Frankenstein Syndrome Questionnaire (FSQ) was used in this study to measure acceptance, it will describe this questionnaire in more detail. The FSQ is a psychological tool created to "assess the acceptance of humanoid robots," including the expectations and anxieties that people have regarding this technology, on a seven-point Likert scale. The authors who developed the scale based it on the "Frankenstein Syndrome," which suggests that Western cultures tend to be more afraid of humanoid robots than Eastern cultures, such as Japan. To create the questionnaire, a pilot study was conducted with Japanese and British university students, in which feedback was obtained on the dissemination of humanoid robots and their future role in society. Studies were conducted and exploratory factor analyses were used to evaluate data related to people's attitudes toward humanoid robots. Four and five-factor solutions were found, which included different subscales related to anxiety, trust, and expectations regarding humanoid robots. In a subsequent study, the questionnaire development team investigated how the factor structure could vary with age and found a three-factor solution, with subscales related to negative attitudes, expectations, and anxiety regarding humanoid robots (Nomura et al., 2012).

Material and Methods

A cross-sectional study was conducted in a collaborative experimental environment during a assembly of a car engine. This collaboartive workstation was designed for demonstrating a scalable and flexible approach to production, that can be integrated with factory planning, optimization and maintenance systems for further improving productivity and efficiency.

Sample

In this study participated 30 university students (63% female and 37% male), aged between 22 and 26 years old, with no prior industrial experience with cobots and no identified musculoskeletal or other psychological problems. Table 1 shows the participants' sociodemographic data. The sample was divided into two groups: Group 1 (with instructions on the collaborative station) and Group 2 (without instructions on the collaborative station).

Experimental collaborative scenario

A workstation that involves HRC is capable of performing various assembly tasks in the industrial sector. In the collaborative workstation used in the study, augmented reality technology is used. This system allows the active work zones to be displayed in 3D to the operator and provides text and video instructions to guide the operations that must be performed by both the operator and the robot at each assembly step. This situation helps operators in their tasks and allows a better understanding of the robot's behavior, improving collaboration between the operator and the robot.

Table 1. *Participants' characteristics (N=30).*

	Group 1 (*M* ± *SD*)	**Group 2 (*M* ± *SD*)**
Age (years)	22.4 (±1.06)	22.4 (±0.74)
Weight (Kg)	68.6 (±16.50)	63.1 (±7.63)
Height (cm)	170.0 (±8.60)	168.0 (±8.00)
Body Mass Index (Kg/m2)	23.5 (±4.60)	22.3 (±2.00)

Procedure and Instruments

Participants began to assemble the motor at the collaborative station with the robot. In the end, they completed a acceptance scale – The Frankenstein Syndrome Questionnaire (FSQ) – Portuguese version. The FSQ is a psychological tool used to measure human acceptance of robots, as well as expectations and anxieties regarding this type of technology. It consists of 27 items, to which a score is assigned on a scale of 1 to 7 (1: "Strongly disagree", 2: "Disagree", 3: "Disagree a litle", 4: "Not decidable", 5: "Agree a litle", 6: "Agree", and 7: "Strongly agree"). These items were divided into 4 subscales: (I) negative feelings toward the existence of collaborative robots, and their influence into organizations; (II) negative feelings toward troubles and risks collaborative robots may cause in organizations; (III) trustworthiness for persons and organizations related to the development of collaborative robot, and (IV) positive feelings toward collaborative robots that appearing in the organizations.

Data analysis

The statistical analysis of data was carried out using IBM SPSS Statistics software, version 28.0, to analyze and process the data. Descriptive and inferential statistics were used to address the study objectives. Two descriptive measures, mean and median, were calculated. To assess the reliability and stability of the results, a 95% confidence interval was used, with a significance level of 5% ($\alpha = 0.05$). Regarding inferential statistics, the normality assumptions of the variables were first verified. For this purpose, the Shapiro-Wilk normality test was used, taking into account the sample size ($n < 50$). The Spearman correlation test was used to compare the subscales of the FSQ.

Results and Discussion

Based on previous studies, the FSQ was divided into four subscales: "negative feelings toward the existence of collaborative robots, and their influence into organizations"; "negative feelings toward troubles and risks collaborative robots may cause in organizations"; "trustworthiness for persons and organizations related to the development of collaborative robots", and "positive feelings toward collaborative robots that appearing in the organizations". Table 2 shows the items according to the subscale where they are included, as well as the means and standard deviation, divided by group. This scale of acceptance of the robots allowed us to perceive that there is homogeneity in the data obtained since the values are very similar between the two groups. There is statistical evidence, at a significance level of 0.05, to state that the subscales "negative feelings toward the existence of collaborative robots, and their influence into organizations"; "negative feelings toward troubles and risks collaborative robots may cause in organizations"; "trustworthiness for persons and organizations related to the development of collaborative robot", and "positive feelings toward collaborative robots that appearing in the organizations" are identical between group 1 and group 2.

According to Table 3, there are one significant correlation between the "negative feelings toward the existence of collaborative robots, and their influence into organizations" and "negative feelings toward troubles and risks collaborative robots may cause in organizations" subscales ($p < 0.05$). As per the literature, Syrdal et al. (2013) found that it is necessary to relate the FSQ subscales to obtain a deeper validation of this questionnaire and a greater understanding of individuals' attitudes towards cobots. In this study, the observed correlation is positive and moderate, which is not surprising because both dimensions refer to negative feelings related to collaborative robots. Despite the homogeneity of the sample, it included 19 women and 11 men who provided very distinct responses to the questionnaires and were analyzed together, without any separation.

Table 2. *Subscales and FSQ items*

Subscale and items	Group 1 ($M \pm SD$)	Group 2 ($M \pm SD$)	*p*-value
Negative feelings toward the existence of collaborative robots, and their influence into organizations			
The development of collaborative robots is an affront to nature	2.67 ± 1.54	1.93 ± 0.88	
The development of collaborative robots is a curse.	2.00 ± 0.93	2.13 ± 1.06	
I feel that in the future, society will be dominated by robots.	4.27 ± 2.05	3.27 ± 1.79	
I am afraid that collaborative robots will encourage us to interact less among co-workers	3.87 ± 1.77	4.00 ± 1.85	
I am afraid that collaborative robots will make us forget what it is like to be human.	2.67 ± 1.84	3.00 ± 2.07	
The technologies used for the development of collaborative robots belong to scientific areas that humans should not study.	1.80 ± 1.08	2.33 ± 1.11	0.520
Collaborative robots can make us lazier.	4.47 ± 2.13	4.60 ± 2.03	
I don't know why, but collaborative robots scare me	2.73 ± 1.79	2.00 ± 1.31	
Too many collaborative robots in a society could make it unfriendlier	4.80 ± 1.37	4.27 ± 1.98	
Something bad could happen if collaborative robots turn into humans.	4.93 ± 1.53	4.13 ± 2.26	
I would hate the idea of collaborative robots or artificial intelligence making judgments about things.	5.13 ± 1.51	4.67 ± 1.68	
The widespread use of collaborative robots would take jobs away from people.	4.93 ± 1.79	4.53 ± 2.07	

Negative feelings toward troubles and risks collaborative robots may cause in organizations			
If collaborative robots cause accidents or problems, individuals and organizations related to their development should pay appropriate compensation to the victims.	6.27 ± 0.96	5.73 ± 1.28	
I would feel uncomfortable if collaborative robots actually had autonomous emotions and thoughts.	4.73 ± 1.83	4.27 ± 2.28	
Collaborative robots should perform dangerous tasks, for example high physical load and/or high accident risk	6.60 ± 0.63	6.47 ± 0.64	0.307
I feel that if we become overly dependent on collaborative robots, something bad can happen.	4.53 ± 1.64	4.33 ± 1.95	
The widespread use of collaborative robots assumes that it will be more expensive for organizations to maintain them.	4.47 ± 1.30	3.93 ± 1.34	
Trustworthiness for persons and organizations related to the development of collaborative robots			
I can trust the people and organizations developing collaborative robots	5.13 ± 1.13	5.60 ± 1.18	
I trust people and organizations that develop collaborative robots to disclose sufficient information to the public, including negative information	5.00 ± 1.51	4.87 ± 1.36	0.602
The people and organizations developing the collaborative robots will take into consideration the needs, thoughts, and feelings of their users.	4.47 ± 1.55	4.67 ± 1.45	
The people and organizations developing collaborative robots are well-meaning.	5.07 ± 1.28	5.40 ± 1.06	
Positive feelings toward collaborative robots that appearing in the organizations			
The interaction of workers with collaborative robots may sometimes lead to problems in the relationship between workers	4.13 ± 1.55	3.87 ± 2.17	
Collaborative robots can make our lives easier.	6.13 ± 0.83	6.13 ± 0.74	
I don't know why, but I like the idea of collaborative robots.	4.93 ± 1.71	5.07 ± 1.10	
Collaborative robots should perform repetitive and monotonous tasks instead of these being performed by workers.	5.80 ± 1.15	5.73 ± 1.16	0.691
Collaborative robots can be very useful for older workers and/or those with some degree of disability/inability.	6.27 ± 0.88	6.60 ± 0.63	
Collaborative robots can create new forms of interaction both between humans and between humans and machines	6.00 ± 0.76	6.20 ± 0.78	

***Table 3.** Correlations of FSQ subscales*

	I	II	III	IV
I	---			
II	0.65**	---		
III	-0.31	-0.18	---	
IV	0.10	0.08	0.33	---

(*p < .05, **p < .01)
(I) negative feelings toward the existence of collaborative robots, and their influence into organizations
(II) negative feelings toward troubles and risks collaborative robots may cause in organizations
(III) trustworthiness for persons and organizations related to the development of collaborative robot
(IV) positive feelings toward collaborative robots that appearing in the organizations.

Limitations

This study was not free from limitations that could potentially serve as directions for future studies. The first and most challenging limitation was the insufficient literature on the application of the FSQ. The small number of participants was also a limitation. Studying the acceptance aspect in HRC is complex and highly challenging.

Conclusions

In this study, a collaborative robot was chosen as an example in a motor assembly line. The inclusion of collaborative stations aims to optimize and improve production lines, increasing the productivity of the automotive industry. With the development of this study, the goal of measuring robot acceptance, using the preliminar portuguese version FSQ was achieved. However, since the sample was not homogeneous, with a higher percentage of female participants, it was not possible to verify if there were differences between group 1 and group 2. To understand if providing instructions at the collaborative station would be an asset for robot acceptance. In the future, it would be interesting to include an equal number of male and female participants of different ages and educational levels to understand how these variables could influence the acceptance of these technologies.

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