USER EXPERIENCE AND ACCEPTANCE REGARDINGS OF PERSONS WITH DISABILITIES COLLABORATING WITH ROBOTS IN INDUSTRIAL ENVIRONMENT

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Abstract

This paper addresses acceptance and usability of human-robot-collaboration (HRC) for individuals conducted in two experiments. In the first experiment, the control group was composed of people without disabilities and the test group was formed out of people with disabilities employed in sheltered workshops. In the second experiment, the control group was composed of people with a technical background, e.g., engineers, and the test group was formed out of people without a technical background, e.g., social workers. Both experiments compare HRC approaches between the control group and the test group, and the recording was performed using the scientific models UTAUT (Unified Theory of Acceptance and Use of Technology), USUS (Usability, Social acceptance, User experience and Societal impact) and SUS (System Usability Scale). The evaluation of the experiments brought several interesting findings to light. One of the first experiment, e.g., is the test group's higher level of technology acceptance after conducting the experiment than before. An example of the second experiment is the raise in expected performance of the test group after the modification task was done, what reflects a higher degree of which the test persons believe that using the system will help them to attain gains in job performance. Both experiments are listed and discussed. As a conclusion, it can be summarized that Cobots can be applied in sheltered workshops and modern control systems can be implemented and controlled by the supervisors. The new way of working collaboratively is generally welcomed.

Keywords: *Collaborative Robot, Cobot, Disabilities, Technology Acceptance, UTAUT, Usability, USUS, SUS*

1. INTRODUCTION

There is a lot of potential in the research field of human-robot-collaboration. Current obstacles for successful applications can be found in the technical context (e.g., sensors or complexity of robot programming) as well as on the human side (e.g., acceptance or usability). Regarding IFR (2022), the number of installed Cobots had a share in the worldwide robot market of tiny 2.8% in 2017, but the number has increased to a share of 7.5% in 2022.

Further, there is a group in our society that needs support in daily life and in workplaces: people with disabilities. In Europe, this group is 16% of all habitants (European Union Agency for Fundamental Rights) whereas 9.5% of all Germans have an accepted severe disability and many of them work in the industrial environment or in sheltered workshops. (Wetzel and Rathmann, 2020) To promote inclusion, the German government imposes equalization fees for companies that have more than 20 employees and do not employ people with disabilities. In 2019, 61% of German companies with more than 20 employees paid equalization fees (REHADAT, 2021), which could be avoided, at least partly, when orders are given to sheltered workshops.

To combine HRC, the avoidance of equalization payments and the promotion of inclusion, two main theses were developed: "Could people with disabilities be supported in their work tasks by a Cobot in sheltered workshops and would they accept the HRC?", and mainly for a sustainable implementation "Would people without a technical background accept Cobots in applications and would they be able to perform modifications of Cobot applications?".

Thus, the paper's target is the finding, if people with disabilities can control human-robot-collaboration systems. Further, scientific knowledge regarding acceptance engineering of the target group is regarded.

2. STATE OF THE ART

By researching similar projects, it can be said that there are some projects in the industrial environment. In sheltered workshops, nothing could be found.

One project is called MindBot, which is funded by the European Union's Horizon 2020 research and innovation program under grant agreement No 847926 and runs from 2020 until 2023. There, several companies and institutions from European Countries are involved, e.g. the robot manufacturer KUKA or the University of Rijeka, Croatia. The idea behind MindBot is to support the worker's motivation and engagement. This should happen within the Cobot-worker area in a flexible and personalized interaction. Thus, the facilitation of active and positive job experiences is the target. Further, the prevention of negative experiences of anxiety or boredom and apathy is addressed. (I.R.C.C.S. Medea, Associazione La Nostra Famiglia, 2021)

Another project is called "AQUIAS" (Fraunhofer IAO, 2019) and describes HRC in a German company called ISAK gGmbH (see Fig. 1). It was conducted by a consortium of ISAK gGmbH, Robert Bosch GmbH, who developed the (skin of the) robot and the Fraunhofer Institute and was financially supported by the German Federal Ministry of Education and Research. The implementation of the robot is within an assembly line, where the robot assembles shower heads together with a disabled person. According to Fraunhofer IAO (2019), the testing of the assembling process lasted until 2019 and so the project is already finished.

Fig. 1. Project AQUIAS

Source: Fraunhofer IAO (2019)

The last project that has to be mentioned is "next generation". There, Caritas, RWTH Aachen university, Machine Dynamics and Robotics (IGMR) and the University of Applied Sciences for SMEs (FHM) of Cologne are the involved parties. The project's target is to improve inclusion by researching on assistant solutions for disabled people. Hereby, a configuration of workplaces is needed so that severely disabled individuals can work there. (Jürgens, 2019)

None of the described projects has intensively included acceptance and usability regarding's, what is primarily addressed in this paper. If Cobot applications in such environments should be established sustainably, this research is indispensable.

3. THEORY

Robots are often used in industrial environments. The reasons for that are rising automation and the constantly shifting fields of jobs. While 41 percent of the US workforce was employed in agriculture in 1900, the number decreased to two percent in 2000, mainly caused by the introduction of automated machinery and new technologies (Autor, 2015). There are two types of robots: industrial and service robots (Ben-Ari and Mondada, 2017). In this paper, only industrial robots are considered. According to DIN ISO 8373, an industrial robot is a programmable manipulator that has at least three degrees of freedom and is used for industrial applications.

In the described research project, a the Cobot Panda from Franka Emika with collaborative abilities was used. Concerning to FRANKA EMIKA GmbH (2023), the Cobot is the industry-certified system that easily transforms process knowledge into robotic automation – thanks to simple operation and powerful, intuitive interfaces. Plug-and-use setup, connectivity and easy programming via modular app building blocks help you recoup and scale the investment quickly. The Cobot can be seen in Fig. 2.

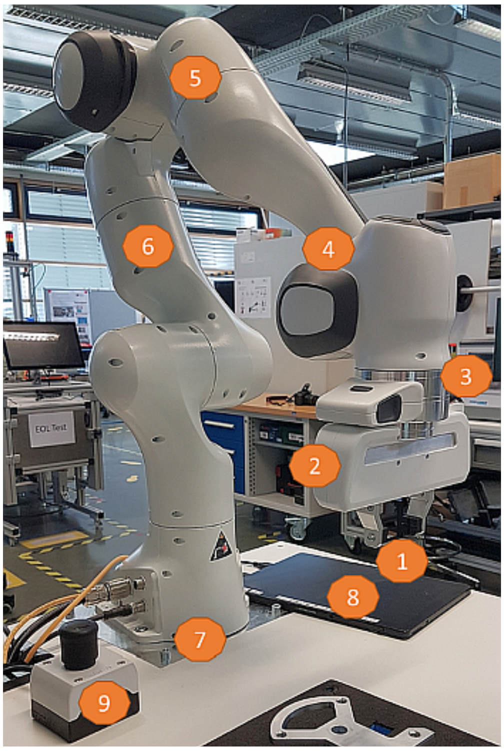

Fig. 2. Franka Emika Panda

Sources: IWT Wirtschaft und Technik GmbH, Pott and Dietz (2019)

Further, in Fig. 2 some numbers can be found, which describe the single parts of a robot. There, the complete robot arm design and behavior is based on a human arm. At the bottom there is a base (7) where the robot is fixed, usually with screws on the floor, on the ceiling, on the wall or on a robot cell. Further, industrial robots have some joints (5) with one degree of freedom each, so that the sequential segments can be moved in combination. The arm (6) is the kinematic chain of the robot, whereas in vertical articulated robots the three compact joints are called wrist (4). Number (1) shows the TCP (Tool Center Point), (2) is the gripper and (3) is the so-called flange. (8) is the control PC and number (9) is a switch with that you can switch between programming and operation mode. This switch is for this particular Cobot and cannot be found at each robot.

Pursuant to DIN ISO/TS 15066, there are four kinds of HRC. Firstly, the Safety-related Stop, secondly the Hand-guiding mode. The third is Speed and Distance Monitoring, and the fourth is Power and Force Limitation. All the modes are illustrated in Fig. 3.

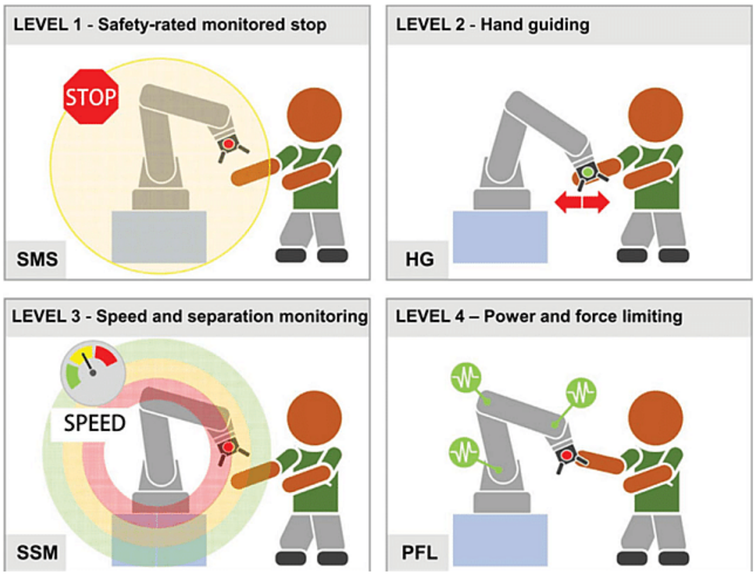

Fig. 3. Collaborative working modes based on ISO 15066 standard

Sources: Villani et al. (2018), DIN ISO/TS 15066

Further, the norm DIN ISO/TS 15066 defines regions and authorized forces when it comes to a collision. The most sensitive region is the face region with a maximum allowed pressure of 65 N. For the hand region it is limited to 140 N which is also the maximum for many collaborative grippers. The used Cobot Franka Emika Panda uses the mode Power and Force Limitation.

Another considered field is disabilities in sheltered workshops. The theory behind disability is a restriction or inability to perform a function or activity in the manner and area considered to be average or accepted functionality that results from an impaired or reduced ability, which may be either permanent or temporary (see DIN EN 63080). A sheltered workshop is a facility that employs people with disabilities. The support of the workshops according to § 102 paragraph 2 SGB IX (Version 14 December 2019) belongs to the special service to participate in working life.

Disabled people were limited to F70 and F71 concerning ICD-10-GM Version 2020 Chapter V (DMDI, 2020). Physical disabilities are not considered in the experiment.

4. EMPIRICAL PART

In the empirical part, the quantitative research methodology laboratory experiment was applied. Thereby, questionnaires and interviews with Likert-Scales (Likert, 1932) were used for test persons. The statistical analysis methods were mainly Cronbach's Alpha, T-Test Analysis and Pearson Correlation.

4.1. Acceptance Measurement

For acceptance measurement, UTAUT from Venkatesh et al. (2003) was used, where Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC) and Behavioral Intention (BI) are the key aspects. An illustration of the model can be seen in Fig. 4.

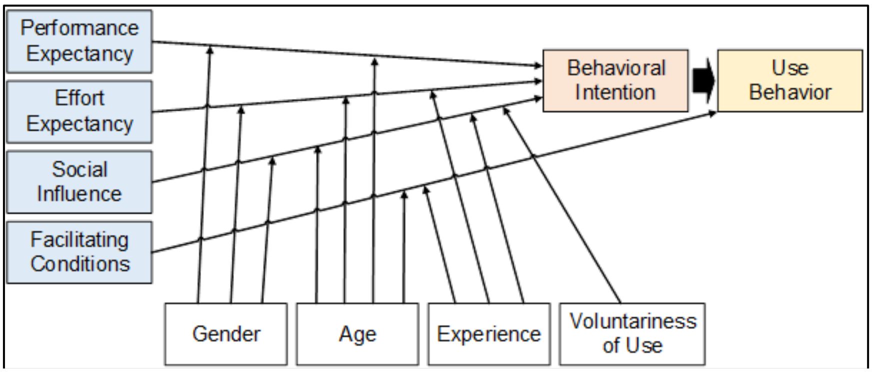

Fig. 4. Research Model UTAUT

Source: Venkatesh et al. (2003)

In addition to the model UTAUT, the Employability was evaluated. According to Wolbring (2016), Employability is an essential consideration when acceptance in a robotics environment is analyzed. He also mentions that people sometimes become nervous that in a long-term view, robots could replace them regarding the job and that is why some do not want to get in touch with new technologies.

4.2. Usability Measurement

To measure usability, parts of the USUS Framework (Weiss et al., 2009) with the indicators Effectiveness, Efficiency, Learnability, Flexibility, Robustness, and Utility were applied. The model is set up like followed:

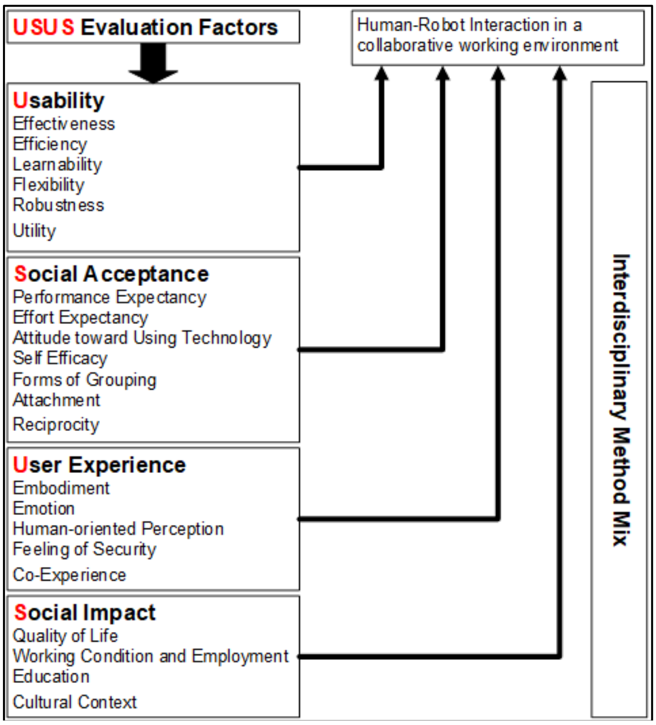

Fig. 5. USUS Framework

Source: Weiss et al. (2009)

The last model was SUS (Brooke, 1996) and consists of ten defined questions and a guided evaluation method to receive a fast and rough estimation about the usability behavior of a system. The usability measurement of the model is:

- > 80.3 → Grade A → Excellent (Adjective Rating)
- 68-80.3 → Grade B → Good (Adjective Rating)
- 68 → Grade C → Okay (Adjective Rating)
- 51-68 → Grade D → Poor (Adjective Rating)
- < 51 → Grade F → Awful (Adjective Rating)

4.3. Test Persons and Environments

There were 30 people in test group and 60 in the control group of the first experiment (regarding disabilities), both with a homogenous distribution of age and gender. In the second experiment (regarding people without technical experience), the test and control groups were each 30 people. Experiment one was performed in a sheltered workshop and the second one in a laboratory.

Fig. 6. Conduction of the experiment in a sheltered workshop

Source: IWT Wirtschaft und Technik GmbH

4.4. Assembly Process and Product

The task of the experiment was to assemble a product with a Cobot and to fill out a questionnaire/conduct an interview before and after it. The product that has to be assembled is the Cranfield Assembly Kit that can be seen in Fig. 7.

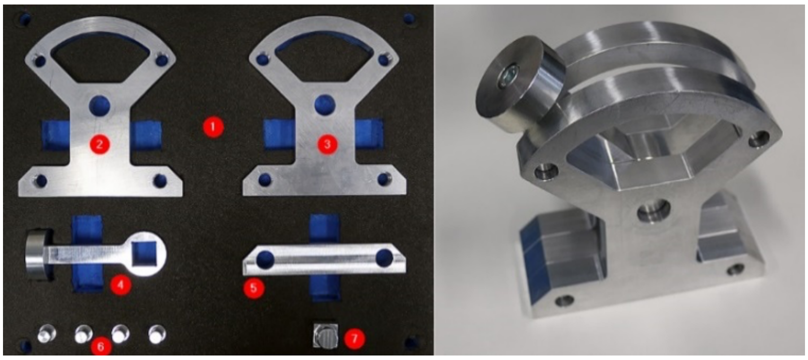

Fig. 7. Cranfield Assembly Kit before and after assembly task

Source: IWT Wirtschaft und Technik GmbH

The questionnaires were oriented to the scientific models UTAUT, USUS and SUS. In the following illustration, an example of a question can be seen:

2.	I think that my performance of the assembly task would be better with a Robot than without a Robot.				
	☐ Strongly agree	☐ Agree	☐ Neutral	☐ Disagree	☐ Strongly disagree

Fig. 8. Example: question in the questionnaire (before experiment 1)

Every question was connected to a code and then evaluated with the software SPSS from IBM.

For experiment one, the task was only to assemble the product. How the assembly process works can be seen in this video: https://youtu.be/8PxhJ3KC12A. The following steps needed to be done:

- Step 1: Activate robot (Make robot performing an action)
- Step 2: Base Plate assembled (Robot has assembled the baseplate)
- Step 3-10: Assembling of Supporting Pins (Human assembles of all four supporting pins)
- Step 11: Activate robot (Make robot performing an action)
- Step 12: Separator assembled (Robot has assembled the separator)
- Step 13-14: Assembling of Shaft (Human assembles the shaft)
- Step 15-17: Assembling of Pendulum (Human assembles pendulum)
- Step 18: Activate robot (Make robot performing an action)
- Step 19: Top Plate assembled (Robot has assembled top plate)

In the second experiment, the test persons had to also perform a program modification by teaching the Cobot. Everything was conducted after an introduction session, where the participants had the chance to assemble the assembly kit without a Cobot, and it was explained which tasks the human performs and which the Cobot.

5. DISCUSSION AND CONCLUSION

5.1. Experiment 1

In the first experiment, an interesting result is the increase in the acceptance for test group after the experiment (Fig. 9), especially in PE, SI, and FC. For the control group, however, PE has dropped, indicating their perception that they could have performed the task better without the robot. Regarding Employability, the test group's mean raised dramatically, whereas the control groups stayed. This means the test group was scared after the experiment the robot could replace their workforce. Concerning usability, the control group rated the system as "good" and the test group as "poor". This may be caused by the circumstance that people, especially with physical deficits couldn't use the setup as desired.

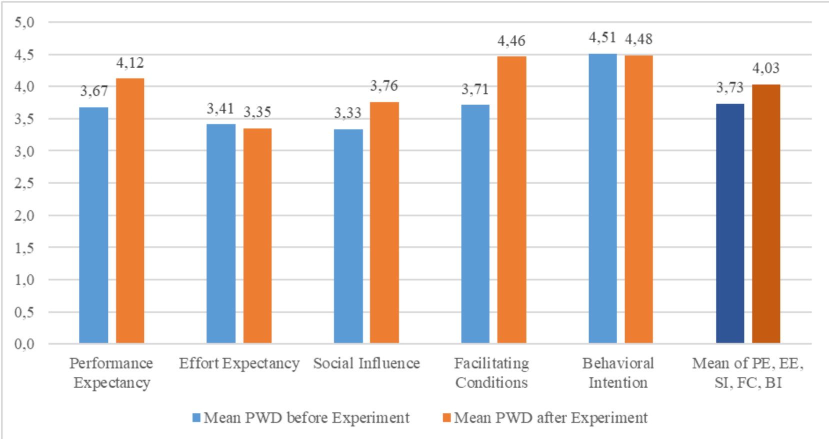

Fig. 9. UTAUT results for people with disabilities, experiment 1

5.2. Experiment 2

An interesting result of the modification part of the second experiment is an increase in the test group's PE after the task. This could be interpreted as a higher degree of the test person's belief that using the system will improve their job performance. Regarding usability, the Learnability value is higher for the control group than for the test group, meaning that people with a technical background think the system can be learned easily, whereas people without technical expertise do not think the same.

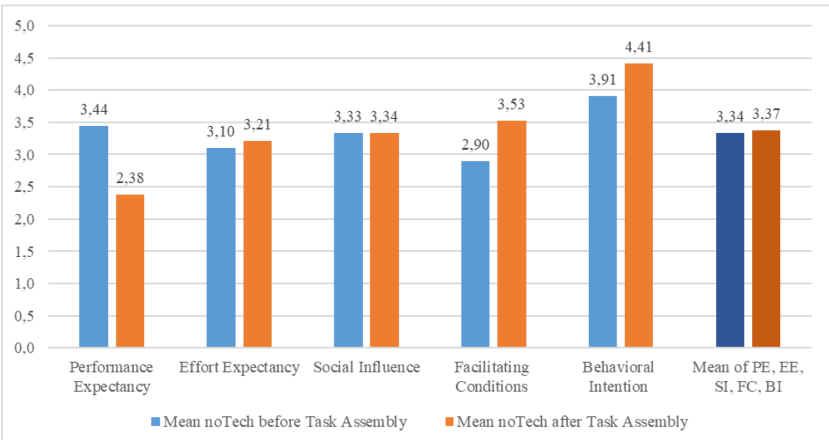

Fig. 10. UTAUT results, experiment 2

Concerning the employability, both groups were not scared that a robot could overtake their work in a long-term view (both values are 2.40).

6. OUTLOOK AND FURTHER APPROACHES

From this project, many further scientific approaches can be derived and there are many potentials for further projects. As the experiment was conducted only once, another approach could be to observe the situation in a long-term view. Further, the experiments could be extended to include other technologies like Augmented Reality. A further delimitation and classification of the different kinds of disabilities could be researched in further scientific works.

Moreover, the separation and consideration of the different kinds of disabilities could be researched in an additional project. As this paper has focused on mental disabilities, also psychological or physical disabilities could be considered.

Finally, the project could be extended to industrial environments in companies. As this project was conducted in sheltered workshops and in the laboratory, also research in a company could be fruitful.

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