User Experience Goals for Designing Industrial Human-Cobot Collaboration

A Case Study of Franka Panda Robot

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ABSTRACT

Pleasurable user experience (UX) is an essential design target in human-technology interaction. It helps to fulfil users' expectations and to complete tasks successfully, in both everyday life and work contexts. In the industrial context, collaborative robots (cobots) are developed to reduce users' workload. In this context, the human workers and cobots share tasks and the workspace. Traditionally, design of such machinery has focused on functionality and safety. One approach that focuses on designing for broader aspects of pleasurable user experience is *experience-driven design* (EDD). EDD allows UX designers to identify and design for certain experiences using *experience goals*. In this study, we explored experience goals suitable for the design of human-cobot interaction. We observed and interviewed 22 participants in a laboratory setup, where they performed a collaborative task with Franka Panda cobot. As a result, we identified four prominent UX goals: *fellowship and sympathy; inspiration; safety and trust; and accomplishment.*

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); HCI design and evaluation methods; User studies.

KEYWORDS

User Experience, Experience-Driven Design, UX Goals, Industrial Robots, Collaborative Robots, HumanCobot Interaction

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1 INTRODUCTION

Human-robot collaboration has become a significant research area in the context of industrial robots [8, 58]. The conventional industrial robots such as ABB IRB 1400 and IRB 2400 [25], are meant for assembly operations, arc welding, laser cutting, etc. They work at a high speed inside cages and are often laborious to install and program, and in many cases they replace factory workers. Collaborative robots or *cobots* are developed to work within the periphery of human working space (Figure 1) without any safety barriers [13, 19] and they are less complicated to install and operate than conventional industrial robots [14]. Thus, the strenuous and repetitive tasks can be assigned to the cobot while the factory workers can concentrate on the tasks that require special skills. Rather than replacing the factory workers, cobots aim to collaborate with them to reduce their strain. The workers or *operators* need to program their own tasks and collaborate with the cobot [16]. In fact, cobots are expected to be easily programmable to allow the workers to program and collaborate with them. The motions are programmed before the collaboration starts and the robots' motions can be easily reprogrammed if the task requires. This is particularly beneficial for small and medium sized companies which do not have experts for complex programming [14]. Thus, programming the robot's motion along with collaborating with it during the tasks to be completed, forms the human-cobot interaction.

Franka Panda [26], UR3 [1] and UR5 [51] are examples of arm-shaped collaborative robots. They are lightweight and safe to use. In addition, these cobots have an easy-to-use programming interface, and up to 7 degrees of freedom [25]. Since human workers work closely with collaborative robots without safety barriers or cages, safety is one of the main concerns or goals while developing cobots [38, 53]. ISO 102181:2011 standard [28] sets requirements for the collaborative robots, such as limited speed, power, force, etc. To this end, robots like Franka Panda, UR3 and UR5 are manufactured with round edges as well as limited speed and force to ensure the safety of the users.

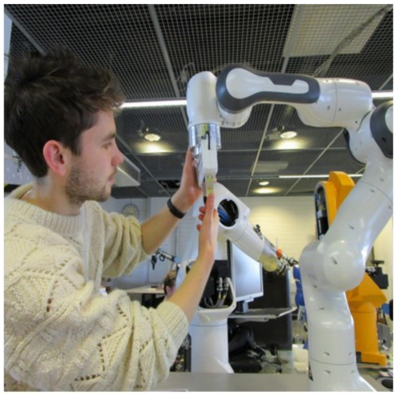

Figure 1: A human working with a Franka Panda collaborative robot (cobot).

Even though safety is a central concern in human-cobot interaction, the broader perspective of *user experience* (UX) is a further crucial aspect for the design of collaborative robots. UX refers to the human experiences evoked while interacting with a technology [21, 22, 26]. According to Hassenzahl et al. [22, 23], to evoke positive user experience, an interactive technology or product must aim to satisfy certain *user experience goals* (UX goals) defined for it. UX goals are the aimed experiences that users are expected to gain while interacting with the technology [22, 52, 53]. Similarly, in the context of human-cobot interaction, designers should target at UX goals that may enhance the quality of interaction by evoking positive experiences with the cobot.

Positive UX can help improve the wellbeing of the operators in the work context. Collaborative robots are developed and designed to be easily programmable for small collaborative tasks. Typically, the work with the cobot consists of small programming tasks and collaboration with the cobot, while the cobot is conducting the tasks programmed to it. Nevertheless, the industrial workers might not have the expertise nor confidence in this field due to the novelty of the technology, or due to the lack of proper programming skills. Thus, the use of the cobot might lead to anxiety and create mental load for the workers. Such stress might cause serious health hazards like cardiovascular diseases in the long run [35]. Pleasurable UX might help reduce users' stress and anxiety, and help them collaborate with cobots conveniently.

The aim of this research was *to understand user experience (UX) of human-robot interaction (HRI) in the context of industrial collaborative robots (cobots)*. Thus we conducted a preliminary study to explore the prior mentioned context in HRI. The research approach is *Research through Design* [1], in which design-relevant concepts are abstracted out from empirical user study findings. Based on the case study of the Franka Panda cobot conducted with 22 users, we define *the UX goals for human-cobot interaction*. UX goals have previously been explored in context of social robots, i.e. robots that communicate with human beings in social tasks [2, 11, 30]. However, to the best of our knowledge, there has been no academic research on exploring UX goals for industrial collaborative robots. Although Kaasinen et al. [29] explored UX goals for industrial systems such as cranes, the context is somewhat different as in those studies the interaction took place through remote operation. Moreover, there is a limited possibility to interact directly with the crane and form a bond with it. In the context of cobots, there is a possibility to bond socially with the robot [17, 46], as the workers share the same space and collaborate with it. Hence, it is important to understand the overall UX with industrial cobots and what UX goals are feasible for design. Thus, we set the following research questions for our preliminary research:

•RQ1: What user experiences arise during the human-cobot interaction with Franka Panda?

RQ1a: What user experiences arise while programming the cobot?

RQ1b: What user experiences arise while collaborating with the cobot?

•RQ2: What are feasible UX goals for human-cobot interaction?

2 RELATED WORK

In Section 2.1, the concept of user experience is briefly reviewed. In Section 2.2, we focus on related work on experience goals. Then, the earlier human-centred studies of industrial cobots are presented in Section 2.3. Based on the Sections 2.1-2.3, we then summarise the UX goals that can be relevant for the human-cobot interaction context in Section 2.4.

2.1 User Experience

According to ISO 9241-210:2019, user experience (UX) is the users' apprehension while using a product, system or service and considers all sorts of user perception before, during and after the interaction [27]. Although it is not possible to compel the users to encounter positive experience, it is feasible to aim to design for that. For example, Hassenzahl et al. [20] describe a wake-up light and how it is designed for a pleasurable waking up experience. They also mention that people tend to invest on experience rather than on monetary goods. It is worth mentioning that two components play a vital role in shaping pleasurable experience in human-technology interaction; pragmatic and hedonic attributes. Pragmatic attributes allow a user to complete a task easily and efficiently [22, 23]. For instance, usability is an essential pragmatic attribute, which supports clear and predictable interaction to achieve the goals. For example, a simple alarm clock possesses pragmatic attributes if it helps the users achieve the "waking up in the morning" goal by ringing at the desired time. On the other hand, hedonic attributes deal with the evoked emotion during the human-technology interaction. Stimulation, identification and evocation help define the hedonic qualities of a product [22]. For better understanding, we reuse the example of wake-up light acknowledged by Hassenzahl et al. [21]. The wake-up light illuminates the room slowly, for instance half an hour before the alarm time, making bird chirping sounds. This evokes memories of waking up in summer even in dark winter. Thus, it helps users go through similar waking up experience, making it pleasurable and refreshing. Similarly, in case of human-cobot interaction, if interaction designers focus on both pragmatic and hedonic attribute, it will enhance the overall UX of cobots. This is important because, just like any other interaction technology, humans closely interact with cobots while collaborating with them. Negative emotions, such as fear or distrust, might result negative UX, thus demotivating the users for long term interaction.

Both pragmatic and hedonic attributes play an important role in shaping the overall UX of an interactive system [23]. In case of human-cobot interaction, pragmatic attributes, such as usability and usefulness of cobots [42, 57], are naturally prioritized over hedonic attributes.

2.2 User Experience Goals

According to Väätäjä et al. [52] experience goals (UX goals) are "the experiences that a designer intends the designed system to support for the end-users when they use the system in their activities." (p.2). Users and designers cooperate to identify needs for certain technology, such as system qualities and emotional pleasure, while using the product. Based on the needs, UX goals are established. They guide the product design to achieve pragmatic and hedonic attributes, ultimately leading towards positive user experience [22]. This whole process of identifying and utilizing UX goals throughout the whole design process is known as experience-driven design (EDD) [21].

Although there has not been any studies of EDD or extracting UX goals in the context of industrial collaborative robots, there have been related studies of using the EDD approach to identify experience goals for social robots [12, 31] and industrial systems [29, 32]. Kaipainen et al. [30] conducted a contextual inquiry study with the social robot Pepper [56] in the context of customer service. By conducting semi-structured interviews and observations with the users at a customer service point in Finland, they identified 15 UX goals, for example, *fellowship and challenges*. Similarly, Chowdhury et al. [11] explored experience goals in the context of university guide robot like *nurture and fellowship*. Kaasinen et al. [29] and Karvonen et al. [32] listed the UX goals identified in the context of industrial systems and remote crane operation. These UX goals include *supporting competence* (*supporting users' ability to conduct task efficiently*) and *avoiding anxiety* in the context of smart interaction with cranes and *feeling of safe operation, sense of control* and *experience of fluent cooperation* in the context of remote operation of a container crane.

Apart from social robots and industrial systems, few studies in other context have been conducted with EDD. Korhonen et al. [34] explored playful experience goals in digital games. They developed the PLEX (playful experience) framework with 22 experience goals. PLEX includes goals such as *fellowship, completion, stimulation etc.* Similarly, Hekkert et al. [24] reported an experience goal *connection* (*feeling connected and secured*) in the context of printing machine, which is a valuable experience to strengthen the bond between human and machine. Lu et al. [36] developed a design framework for work tools to evoke meaningful experience at work and identified UX goals such as *stimulation and trust.* According to them *stimulation* refers to enjoyment of learning in work context. Similarly, Ahtinen et al. [3] identified *stimulation* as an experience goals for pop up workspace. According to them, *stimulation* helps to awaken all senses and inspire the workers.

From the related work presented above, we summarized the UX goals that are potential in the context of collaborative robots in Section 2.4.

2.3 Human-Cobot Interaction

Collaborative robots or cobots are a central technology solution used in the 4th industrial revolution or Industry 4.0 [44]. According to Romero et al. [44], one of the benefits of the cobots are that they do not need to be caged, thus saving space that would be needed for the safety barriers. Even though cobots move slowly and are developed to be safe to work with [14], users' perceived safety and trust are major concerns in this scenario. There have been several studies related to perceived safety and trust of collaborative robots [39, 40, 54]. Researchers have developed augmented reality based applications to predict collisions [36], gesture application of safe interaction [38], mixed reality based application for safe operation [45] etc. all to ensure perceived safety in human-cobot interaction.

However, there are also other factors, which influence UX in human-cobot interaction. Weiss et al. [55] reported that workers could take small chat breaks at their convenient times before robots were introduced at work. The cobots control the workflow of the workers restricting them from social interaction at their will. Although few workers valued the installation of the robots in assembly line after few weeks, initial mental and physical adjustment was highly demanded [55]. Some workers also reported that cobots slowed down their working speed [55]. On the other hand, Saupper et al. [45] reported in their study that users tend to develop social relationship with the cobots when they work on the same floor. These are few results that reflect some aspects other than safety related to UX while interacting with cobots.

As we explore UX of human-cobot interaction, it is worth mentioning the interaction techniques that has been explored in this context. Since it has been a trend to make interactive technologies affective, there has been similar attempts in case of cobots [35, 47]. Affective computing is the process to develop systems and devices to acknowledge and interpret human affect [35]. Baxter and Sawyer robots interact affectively with their users via facial expressions, indicating the robots' status and progress [9]. In addition to affective computing, the interaction with robots are made more convenient by introducing hand guiding mode for cobots. Franka Panda robot is one example of such a robot [27]. The complex motion teaching can be easily achieved by moving the robot manually from one point to another and saving the location points by a web interface provided by Franka Emika [26]. Another method to interact with cobots is via teach pendants, which are control boxes to program motions for robots, for example, in ABB [24] and KUKA robots [16]. All the prior mentioned interaction methods are commercialized. Apart from the commercially available techniques, researchers have explored cobot interaction via augmented reality [41], natural language [47] etc. Robot motion programming and human-robot collaboration are conjointly responsible for users' experience with the cobot [15]. As mentioned earlier, cobots are developed so that workers can program and collaborate with the robot. Therefore, programming the robot via the interface has a vital impact in human-cobot interaction.

Table 1: UX goals from related work that are relevant for collaborative robots (cobots).

UX goals	Original context	Relevance for the cobot context
Feeling of safe operation [29]	Remote operation of container cranes	It is necessary for human workers to feel safe around cobots to collaborate with it efficiently and willingly
Sense of control [29]	Remote operation of container cranes	The human workers should feel that they are in control of the cobot while operating it to avoid stress induced by confusion and anxiety.
Experience of fluent cooperation [24][29]	Remote operation of container cranes	Fluent cooperation and collaboration is relevant in human-cobot interaction to evoke *sense of control* while operating the robot.
Fellowship [5][12][31]	PLEX Framework, university guide robot, guidance robot at service point	Fellowship could be an interesting UX goal in the context of human-cobot interaction to form a strong bond between human worker and cobot.
Connection [24]	Printing machine	Feeling connected with the cobot will evoke fellowship between human workers and cobots.
Security [3][36]	Ambient pop-up workspace, design framework for work tools	The validation of security for human workers is important in the context of human-robot collaboration to *feel safe* around the cobot.
Trust [36]	Design framework for work tools	*Trust* is a valuable experience in this context since it is a prerequisite for experiences like *fellowship, experience of fluent cooperation and connection.*
Stimulation [3][5][36]	Ambient pop-up workspace, PLEX Framework, design framework for work tools	*Stimulation* is crucial for learning. Since cobots are comparatively novel, there is a requirement for enthusiasm to learn.
Supporting competence [29]	Smart interaction with cranes	Supporting competence for the human workers is vital to help them collaborate with the robot efficiently.
Avoiding anxiety [30]	Smart interaction with cranes	Avoiding anxiety is important to collaborate with the robot without fear or distrust.

2.4 Potential User Experience Goals for Collaborative Robots

Based on the review of the related work, we conclude that understanding the user experience goals in the context of the human-cobot interaction can help designers focus on users' perspective while designing interaction for the cobots.

Fellowship [5][12][31] and *connection* [24] could be relevant on the industrial robotics context because users have the tendency to anthropomorphize technology [14] [43] and industrial cobots have the capability to establish human-robot companionship in the industrial settings [46]. In addition, *feeling of safe operation, sense of control* and *experience of fluent cooperation* are also suitable experience goals for industrial human-robot interaction because the tasks need to be conducted very efficiently and smoothly in this context [29] [32]. Similarly, *trust [36] [38] and security [3] [36]* are significant UX goals in this context because it is important for the workers to feel safe in order to conduct tasks without stress or fear . Furthermore, these UX goals will reduce users' stress and help them learn about the robot efficiently [47]. The UX goal *stimulation* [3] [5] [36] will help users to learn about the cobot in an enjoyable manner and inspire them to work with it. All of the above mentioned UX goals could play a role to strengthen the bond between users and cobots.

Based on the review, we list potential UX goals that could be used in design to enhance human-cobot interaction (Table 1).

3 METHODOLOGY

In this section, we describe the research approach and methods adapted to conduct our user study. The study was conducted using the *Research through Design approach* (RtD) [1], to gain understanding of the concepts that can help further to design cobots that can support positive user experience.. We used observations, semi structured interviews and questionnaire as data collection methods to comprehend users' experience in the context of human-cobot interaction.

3.1 Franka Panda Robot as the Platform

We selected Franka Panda robot [26] (Figure 2) as the case robot platform for the study. Franka Panda is a collaborative robot arm with seven degrees of freedom (DOF), and it is advertised as easy to install and program [26]. It weighs 18 kg, has a height of 119 centimetres and a payload of three kg. The robot arm also has a

Figure 2: - Collaborative robot Franka Panda. It has seven degrees of freedom and is 119 centimeters tall.

gripper, which can exert up to 70N grasping force. The robot shows its current status by changing the color of the lights situated on its base. The most important status indications and related colours are: safe interaction with Panda possible (white), Panda can move any moment (blue), Panda is executing a task (green), Panda encountered a conflict signal (pink), Panda encountered error (red) and Panda is locked and cannot be used (yellow). The status of the Panda robot can be changed between "safe interaction" and "executing a task" using external activation device (Figure 2). The device can also be used to halt the movement of the robot while executing a task. The manufacturing company, Franka Emika [26], provides a web interface called *Desk* (Figure 3), which can be used to program Panda robot by hand guiding the robot and using the apps provided [26].

Panda can be programmed for the tasks of *pick and place*, *packaging*, *processing* and *finishing*. Users can create new tasks from the tasks panel (see Figure 3). Creating a new task creates an empty workspace. The user can drag and drop desired applications from APPS panel (see figure 3) and program the robot. "Package Candies" in Figure 3 is a workspace with five applications. The APPS panel provides list of applications, such as *joint motion* (used to make the robot move by manipulating the joints)*, cart motion* (used to make the robot move along Cartesian points), *gripper grasp* (used to control robot's gripper), etc. For instance, if the users wish to move the robot one inch to the right, they can drag and drop suitable application (cart motion or joint motion) from the APPS panel (see Figure 3) onto the workspace. The users can then manually hand guide the robot one inch to the right and store the position in the application. If required, they can easily change the position of the robot by hand guiding it and storing the new position in the application.

3.2 User Study and Tasks for the Cobot

To answer the research questions outlined in Introduction, we designed the study to gain understanding of both the UX of programming the cobot via the web interface (RQ1a) and collaborating with the cobot (RQ1b).

3.2.1 The Study Design. As mentioned earlier we adapted RtD approach to conduct the study. RtD is an approach to utilize design practices, methods and processes to generate new knowledge via conducting research [60]. With the aid of RtD approach we can creatively make objects and process to gain knowledge about human-cobot interaction [59]. RtD gives us the flexibility to enact the industrial situation to understand the unclear agendas [59].

Therefore, we conducted our user study in a robot laboratory (RoboLab) in a Finnish university and asked the participants to imagine it as candy packaging industry. The cobots have been preinstalled under the guidance of engineers in RoboLab [51] and it has been established for research and academic purposes. Since cobots are safe to interact with and Panda robot meets all the safety requirements provided by ISO 10218-1:2011 [28], we did not need to take additional safety measures during the interaction. Moreover, since the robot has been installed and tested by the responsible people in RoboLab.

To this end, we designed a set of tasks for the participants. These tasks were explained to the participants in the form of a collaboration scenario, where they work for a candy packaging factory. Their job would be to teach Franka Panda robot to fetch three candy boxes from one point to another. Once Panda robot brings one box for them, they pick up the box, fill candies and put them in delivery box. (Figure 4).

The participants were given the following three tasks:

Task 0: This was a warm-up task for the participants. In this phase, the users familiarized themselves with the robot by teaching to move the robots sideways and to open and close its gripper.

Task 1: Upon completion of *Task 0*, the participants proceeded for *Task 1,* where they had to teach the robot to reach point A, pick up a candy box, come to point B and give the box to the participant.

Task 2: After one cycle, they move on to *Task 2,* where they taught the robot to repeat the cycle for three times and the participants could fill the boxes with candies. The task ended when the last candy box was filled.

3.2.2 Procedure. Once the participant entered the lab, we explained the purpose and procedure of the study, and took written consent to record the test on video and audio. The participants were assured that the data will be anonymized in the analysis phase. We asked them to fill in a demographic questionnaire (e.g., age, gender, occupation, former experience of robots). Then, the participants were introduced to Franka Panda and the test tasks. The participants were given the test tasks on paper, and they were instructed to perform them one by one. We also instructed them to use the user manual, which was intended to help the users operate the robot. The manual of 149 pages was available in both pdf and hard copy. The manual included introduction to the robot and its related terms, technical specification and safety, instructions to install and start the robot, and guidance for interaction and programming. The approximate length of the study was one and a half hours.

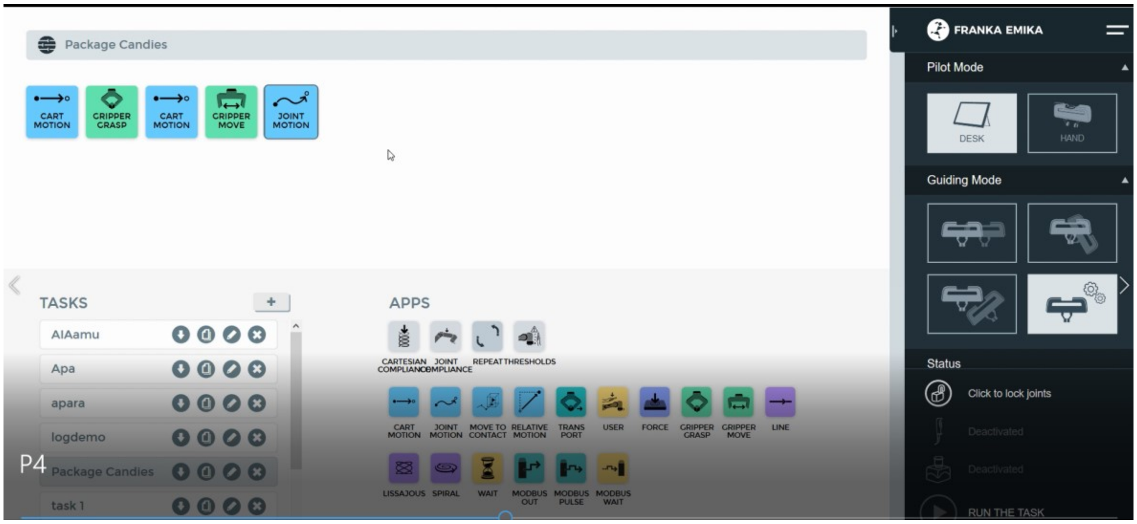

Figure 3: The web interface of Franka Panda called *Desk*. The user can program motions and control the grippers of the robot by dragging and dropping APPS in the workspace.

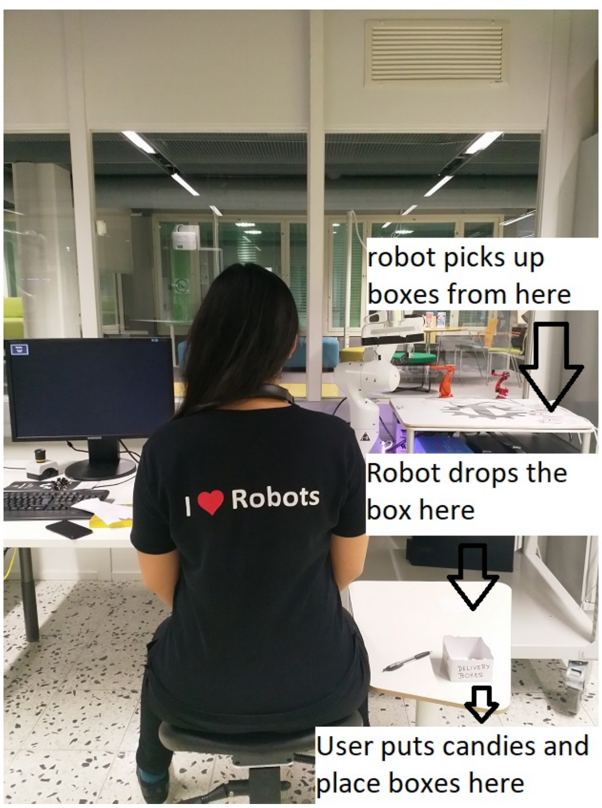

Figure 4: User study setup.

We collected both qualitative and quantitative research data. *Observations* and *semi-structured interviews* were conducted to collect qualitative data. We observed the participants and asked them to think aloud about the challenges they faced, their understanding of the system and their expectations from it during the interaction. From the observed facial expressions, exclamations, proximity with the robot, comments made during think aloud and other behaviours, we identified the evoked experiences during the interaction. After the interaction, we conducted 8-10 minutes long interview with the participants. During the interview, we gained in-depth knowledge about their evoked experience, challenges and interpretation of the system during the interaction. We asked the participants about their overall experience of interacting with the robot; what was positive and what could be improved in such interaction with cobots; how convenient was it to operate the robot and the interface; how to make the interaction pleasurable for them; how was their learning experience, and if they felt any safety concerns during the interaction.

We used the short *User Experience Questionnaire* (UEQ) [49] to quantify the users' experience and to understand, which experiences were intriguing for the participants. The short version of UEQ was used due to time constrains and to avoid the stress of answering a long questionnaire. The participants were requested to fill the form based on the overall experience of programming the robot via the web interface. The short UEQ questionnaire is a seven-point Likert scale questionnaire with the eight items presented in Table 2

3.3 Participants

We invited a total of 22 participants to take part in the study. They were recruited from seminars, meetings and workshops related to Artificial Intelligence, the university's robotics course and via social media platforms. 8 out of 22 participants were female. 18 out of 22 participants had no previous experience with Franka Panda robot. The participants were mainly students (15/22), engineers (4/22), researchers and scientist (4/22). The participants were 23-36 years

Table 2: Items in UEQ questionnaire [48]

Negative	Positive	Scale
obstructive	supportive	Pragmatic Quality
complicated	easy	Pragmatic Quality
inefficient	efficient	Pragmatic Quality
confusing	clear	Pragmatic Quality
boring	exciting	Hedonic Quality
not interesting	interesting	Hedonic Quality
conventional	inventive	Hedonic Quality
usual	leading edge	Hedonic Quality

old and belonged to the millennial generation. This age range was particularly chosen because the requirement and understanding of technology for this generation is different from Generation X (born between 1965-1980). Cobots are emerging technology and they are likely to takeover 34% of the market and millennials with gain most from it [11]. Since millennials are more likely to work with such new generation of cobots in the future, it is important to explore their experience and expectations towards these robots in order to be able to design for pleasurable human-cobot interaction in the future. Table 3 outlines the details of the participants.

3.4 Data Analysis

Interview and observation data were analysed using content analysis method [59]. We transcribed all data from the recordings and categorized the data into two main categories; programming with the interface and collaborating with the robot. We then categorized the data to find out evoked user experiences leading to the user experience (UX) themes found under each of these two categories. In total we identified 11 UX themes for both categories. In addition, we analysed the short UEQ questionnaire by the provided data analysis tool [48]. The data analysis tool provides mean, standard deviation, Cronbach alpha for pragmatic, hedonic and overall experience of the interaction.

4 FINDINGS

Next, we present the findings related to **RQ1a** to identify *the UX of programming the robot via web interface*, based on the UEQ questionnaire, user interviews and observations (Section 4.1). To explore **RQ1b**, we present *the UX related to the collaboration with the robot*, identified during the data analysis of interview and observation (Section 4.2). We answer to **RQ2** by *identifying the UX goals of human-cobot interaction* (Section 4.3) based on the findings of section 4.1 and 4.2. When presenting the findings, we cite the participants' comment in italics along with their code (gender, age).

4.1 UX of Programming the Robot via the Web Interface

To understand the user experience of programming with the robot via web interface, we used the UEQ questionnaire to measure quantitative data, and user interview and observations to collect qualitative data. We asked the participants to answer the questionnaire based on their experience of programming the robot via Desk web interface. All 22 participants filled in the questionnaire and were interviewed and observed.

Table 3: Mean and Cronbach Alpha for pragmatic and hedonic quality dimensions of the web interface

Scale	Mean	Cronbach Alpha	N
Pragmatic Quality	0.80	0.49	22
Hedonic Quality	1.37	0.71	22
Overall	1.09	-	22

4.1.1 Results from the UEQ Questionnaire. The online data analysis tool [48] transformed values per item to a scale of -3 to +3, calculated the *mean for each value*. It successively calculated the mean and *Croncbach Alpha* for pragmatic (*mean= 0.807, Cronbach alpha=0.49*) and hedonic qualities (*mean= 1,375, Cronbach alpha=0.71*). *N* indicates the number of participants for the test. *Cronbach alpha* value greater than 0.7 indicated that the result was consistent. Mean values between -0.8 to +0.8 indicate neutral evaluation, value>0.8 indicated positive evaluation and value<0.8 indicates negative evaluation. The overall user experience was perceived to be positive according to the mean score.

The results indicate that hedonic attributes got higher UX score than pragmatic attributes. In fact, we noticed that *confusing-clear (pragmatic attribute)* scored the lowest mean value (0.2) among all attributes and *not interesting-interesting (hedonic)* scored the highest mean value (2.4) among all attributes. We observed that participants struggled to operate the robot due to ambiguity of terms and features. Most participants were not clear about technical terms and did not prefer to go through the manual for understanding them. Few participants took help from the manual, yet this did not clarify the two functions. The system was developed to support users who have little knowledge about programming in general. Such terms might create confusion and anxiety in the factory environment. On the other hand, Franka Panda was a new technology for many participants, thus it appeared to be interesting how easily the robot could be moved manually to store desired position. "*I wish I could do this easily to Pepper robot" (Female, did not prefer to tell her age).*

The quantitative data are considered to be partial and preliminary at this stage of the research to support the fact that positive UX was ensured during human-cobot interaction in this context.

4.1.2 Observations and Interviews. While the participants programmed the robot using the web interface, we gathered qualitative data on their experience. Based on the UX themes under the category, *programming with web interface*, we identified the following experiences categories. The experiences *Exploration and Discovery* were merged into one, since they are correlated in human-cobot interaction:

Exploration and Discovery. Exploration and discovery were evident during human-cobot interaction as all participants experienced it. 18 out of 22 participants expressed surprise or amusement when they would discover a way to make the robot work according to their wish. One participant commented "*...they made it like a treasure hunt to identify the problem and the solution" (Male, 28).* One participant also discovered how to open a locked gripper ," *Oh! What happened? Magic?"* (Female, 26). Most of the participants were browsing through the web interface to *explore and discover* suitable features to complete the task. Only 3 participants took help from the manual when we suggested it. Features like *"re-initializing gripper", "setting grasping force", "setting weight of the object to be grasped", "collision detection", "how does the robot move from one point to another"* were ambiguous for the users. Hence, there were continuous exploration and discovery during the process of recovering from ambiguity.

*Completion and Accomplishment.*Although 19/22 participants successfully completed the task using the web interface, and 20/22 participants felt *accomplished* to operate the robot with the interface. One participant could not complete the whole task due to time constraints, but she felt accomplished to make the robot work as she wished "*At first I got really anxious, but when I made the robot move, I felt accomplished*" (Female, 24). Participants often expressed words like "*successful*", "*completing the task*", "*finally, it is working*" etc. which referred to their feeling of accomplishment. Moreover, participants would vocalize cheerful words like "*Yay, its working*" (Female, 35), *"Oh, you made it!"* (Female, 28) and "*Yes! Very good!"* (Male, 24). The ones who could not complete the task felt that the allocated time was not enough for them to complete the task.

Suffering (anxiousness, frustration, confusion). All the participants felt either anxious, frustrated or confused during Task 0 and Task 1. 5 participants felt it has a learning curve. "*It takes some time to get used to the system, it is the same with every technology. But I think once you learn it, it will be easy to operate, because it has some nice features.*" (Male, 27). Other participants felt it was somehow their fault if something went wrong or they were not smart enough to perform the task. "*Maybe it is easy for others, but it is not so easy for me*" (Female, 23). Frustration and confusion were often observed when the robot moves somehow differently than the participants' expectation. Participants often got anxious during error states or if the robot hits some object.

4.2 UX while Collaborating with the Robot

Based on the data gathered from participants' collaboration with Franka Panda , we deduced the following experience categories. Based on the UX themes under the category, *collaborating with the robot*, we identified the following experiences categories. We merged few experience categories into one, for example *safety and trust, pride and accomplishment and fellowship and sympathy*, since they are correlated in human cobot interaction:

Safety and Trust

17 out of 22 participants showed signs that they felt safe around the robot while collaborating with it. There were 8 participants who believed that the robot was "smart", and it would stop before hitting someone. These participants also believed that the robot could go much faster as they presumed it to be smart. One participant mentioned that he will feel safe even if the robot moved much faster, "*The robot looks very elegant, so I trust it to have more speed*" (Male,24). One participant mentioned that the robot cannot hit anyone unless they are programmed to do so. "*I trust that the robot will not hit me until I program it to do so*" (Female, 25). However, according to our observation, the participants were often startled or shocked to see the robot colliding with the table. Upon asking, one participant mentioned that "*I was not scared for myself. I felt if something happens to the robot I might need to pay for it. I believe it is expensive*" (Female,25). On the other hand, 4 participants showed signs of distrust towards the robot. *"I never trust these machines, when you were standing close to the robot while it was operating, I was getting anxious"* (Male, 34). One participant felt safe to place her hand over the external activation device (red button) in case something goes wrong. *"After all, these are machines. So, we should be careful". (Female, 28).* In fact, she pressed the external activation device immediately when she predicted potential collision.

*Pride and Accomplishment*17 out of 22 participants could reach the third and final task, the collaboration task (described in 3.1). Upon completing the task, participants expressed joy, relief, excitement and accomplishment. 2 participants also mentioned that they felt proud to work with the robot. "*Super proud to complete the task*" *(Male,28).* For one participant, it was a matter of pride to complete the task, so that she can refer it to her children. "*I feel so proud to work with the robot. I can go home and tell my kids*". *(Female,35).* One participant also mentioned that she felt proud that she was teaching a robot, "*I feel so proud that I am teaching a robot*" (Female, 35). Participants also mentioned that they felt accomplished to complete the task because it was hard for them to figure out how the robot works in the beginning, "*I am proud to complete the task because they made it like treasure hunt to search for problem and solution*" (*Male,28*). In addition, there were participants who felt proud to work with the first time "*I feel successful that I could solve, because this is my first time interacting with this kind of robots*" (*Female, 24*). There were also signs of accomplishment when the participants cheered as the robot moved as per their expectation.

*Fellowship and Sympathy*5 out of 22 participants showed compassion towards the robot. These participants treated the robot as a coworker instead of a machine. Few of these participants used terms like "pal", "buddy" and "good boy" for the robot. Participants often talked to the robot as well. *"Oh, please don't do that" (Female,25). "Are you alright?" (Male,24). "Why are you not working, argh!" (Female,28).* Although the participants did not explicitly mention that they bonded with the robot, the above-mentioned cues were expressing their feelings towards the robot.

Table 4: Mapping of experience categories into UX goals

Experience Categories (Valence)	UX Goals (Valence)
Completion (+), Accomplishment (+), Pride (+)	Accomplishment (+)
Safety and Trust (+)	Safety and Trust (+)
Fellowship and Sympathy (+)	Fellowship and Sympathy (+)
Exploration and Discovery (-), Suffering (-)	Inspiration (+)

4.3 UX Goals

We identified six experience categories from the findings; four primarily positive experiences (*Completion, Fellowship and Sympathy, Safety and Trust, and Pride and Accomplishment)* and two primarily negative categories (*Exploration and Discovery, and Suffering*) . Based on these findings, we suggest 4 UX goals for human-cobot interaction. We mapped the negative experience categories to positive UX goals. Table 4 represents the mapping of experience categories into UX goals.

*Accomplishment*The feeling of *accomplishment* is the most noticeable phenomenon in our study. The participant took it as challenge to complete the task. The reward for them seemed to be the satisfaction of completing the task. The feeling of accomplishment could motivate the workers to perform better and learn about the cobot in the long run. *Completion, accomplishment and pride* are all mapped into one UX goal, since all three goals evoke similar positive emotions, such as, feeling of success, confidence and enthusiasm to work with the cobot. *The feeling of accomplishment serves* as an intrinsic motivation, which persuades the users to interact with the technology better than extrinsic motivation. We observed participants postponing other engagements, for example attending a lecture, to complete the task. "I wanted to complete the task for my satisfaction" (Female,21).

*Safety and Trust*Although *Safety and Trust* is the most common UX goal in human-cobot interaction, it is very crucial in this context. To ensure *safety*, cobots have slow operating speed. During the interaction, only four participants felt that the cobot might hit them. Other participants assumed that the cobot has the capacity to detect collision and would stop before it happens. However, the participants soon realized that Panda robot stopped after the collision in several events. The collision impact was mild, yet it was alarming for the participants. On the other hand, the participants believed that it was up to the workers to program it safely. According to our observation, most of the collision occurred due to the unforeseen paths followed by the cobot. The participants defined a path of motion for the cobot and expected it to follow the path. In such cases, the workers might trust the cobot if they could predict the cobot's motion.

Fellowship and Sympathy During the study, the participants often anthropomorphised the robot by assigning a gender or by having small talk with it. Thus, we establish our first UX goal, *fellowship and sympathy*. *Fellowship and sympathy* will strengthen the bond between human and the cobot as well as reduce the anxiety of interacting with it. In addition, it will help the workers to develop a social affinity towards the cobot. There are instances where robots are treated as co-workers as mentioned in Section 2.3. Also, there are instances where cobots involve in empathic interaction using non-verbal gestures (Section 2.3). In addition, there is a need for workers to have a conversation with the robot.

*Inspiration*In addition to *fellowship and sympathy*, workers' *suffering* can be reduced if they get some *inspiration* to operate it. During our study, we observed that participants often got motivated or inspired to solve issues related to the cobot because they took it as a challenge to achieve their goal. They also mentioned they felt proud to complete the task. 2 participants mentioned words like "treasure hunt" and "playing a game" while interacting with the robot. They commented it was frustrating to figure out few functionalities. Nevertheless, they took the task as a game and felt accomplished afterwards. Thus, we introduce our second UX goal, Currently, the noteworthy *inspiration* to use cobots in the industry is safety. However, for pleasurable humancobot interaction, the workers should be intrinsically motivated.

5 DISCUSSION

In Section 5.1, we discuss about the pragmatic and hedonic experiences, which arose during the human-cobot interaction with Franka Panda, in the light of previous research. Based on the experience categories, derived in Section 4.1 and 4.2, we identify the pragmatic and hedonic UX. As discussed in Section 2.1, both pragmatic and hedonic experiences shape the user experience in human-technology interaction. In Section 5.2, we discuss about the feasible UX goals in the light of previous research. These UX goals are mapped from the experience categories derived in Section 4.1 and 4.2. The negative experience categories were mapped to positive UX goals.

5.1 Pragmatic and Hedonic Experience Categories in Human-Cobot Interaction

In total, six user experience categories were identified from our research data including interviews and observations concerning human-cobot interaction. Interestingly, we identified some overlapping experiences with the PLEX Framework [5], which focuses on a set of playful experiences. *Exploration and discovery,* and *suffering* are examples of overlapping experiences with PLEX Framework [5]. These experiences were considered as negative experiences in our context of industrial cobots, and thus, should not be considered as UX goals in human-cobot interaction. Although *exploration and discovery* are regarded as positive UX in the context of playfulness [33], the same experience is considered as negative in our context due to the stress caused by exploration during human-cobot interaction. In addition, these experiences were evoked due to usability issues, such as lack of efficiency of programming the robot and lack of clarity of keywords and terms [39][49]. Moreover, we also discussed about the learning curve of the system in Section 4.2, which indicates learnability issues of the system. Since these issues are purely pragmatic [21, 49], we classify *exploration and discovery and suffering* as pragmatic experiences. *Suffering* is a critical experience in our case since it is perceived as hedonic experience in several contexts [30, 31]. *Suffering* is a negative emotion and often impacts a person's intrinsic motivation [29]. However, in human-cobot interaction, s*uffering* was commonly evoked due to pragmatic issues. Thus *suffering*, in this context, can be both pragmatic and hedonic experience, as it is evoked due to pragmatic issues and can have a negative impact on users' intrinsic motivation. Due to these negative impacts, designing interaction for *suffering and discovery and exploration* should not be considered in human-cobot interaction.

We also identified *safety and trust* as a pragmatic experience. This is a very important experience in the industrial setting [56] and is commonly considered while developing industrial machines. Kaasinen et al [28] emphasizes that *feeling of safe operation* is a significant UX goal for cranes as they lift heavy load. Similarly, cobots are responsible to help human workers with lifting heavy objects. Any sort of safety hazard can even cost a human life. Thus, we consider *safety* as a pragmatic experience to help human workers perform efficiently. In addition, Maurtua et al. [37] mentioned *safety and trust* is essential to ensure efficient humanrobot collaboration. Efficiency is a one of the foundations of usability, which shapes pragmatic experience of a system.

Accomplishment is considered as hedonic experience in our study. PLEX Framework states that *completion* refers to accomplishing a major task [5]. Thus, it evokes several emotions such as feeling of success, confidence and enthusiasm. Such positive emotions refer to the achievement of hedonic qualities [20]. Similarly, *Pride* is an experience which we consider as hedonic since it evokes positive emotions. The final experience identified in our study was *fellowship and sympathy. fellowship and sympathy* has been observed for both social robot [11, 30] and collaborative robots [41, 45] as robots have the capability to evoke warmth and affection among users. Therefore, we identify *fellowship and sympathy* as hedonic experience.

5.2 UX Goals for Cobots

Our main contribution in this paper is to present four UX goals and practical scenarios to achieve these goals in human-cobot interaction. We have classified these experiences based on three stages of interaction: *before, during* and *after interaction.* These UX goals aims to support the design for positive experiences and to revise the negative experiences to pleasurable ones. Several of these goals have been explored by researchers in different contexts as listed in Table 1 in Section 2.2.

Our first UX goal is **fellowship and sympathy**, which has been stated in PLEX framework [5]. In addition, *fellowship and sympathy* has been explicitly mentioned in the context of learning and teaching robot [2], university guide robot [12] and guidance at city service point [30]. Surprisingly, *fellowship* has also been observed in the context of human-robot collaboration [9] [46]. According to media equation, people tend to treat technology anthromorphically [43]. Sauppe et al. [45] observed how operators treated the cobot, such as their "son", "colleague", "grandson" etc. It was also observed that, operators often had small conversations with the robot, for example they would greet in the morning [45]. Such tendency towards the cobot can improve human-cobot interaction and might help to *avoid anxiety* [29] around the cobot. Additionally, social cues and presence is a vital factor in the industrial settings [6] [17] [18] [57]. However, interaction designers should carefully design social cues, such as non-verbal cues for the cobot, to avoid any negative feeling towards the robot [6]. In addition to nonverbal cues, verbal communication might help to build *connection* [23] with the cobot. While working with robots in the industry, workers often miss the opportunity to chat with their co-workers as robot determines the rhythm of their work [54]. Although cobots cannot completely replace human communication, it can help reduce workers loneliness in the factory settings via verbal communication. As suggested in Section 4.3, cobots can verbally answer to workers' questions or tell a story about itself to build a social bond with the human worker.

Safety and Trust is frequently mentioned UX goal in the context of human-cobot interaction [37] [38] [39] [41] [45]. Undoubtedly, *safety* is a vital UX goal in industrial settings [29] [32]. *Feeling of safe operation [29], security [*3*][36], and trust [*36*][38][41][19]* are related to *safety and trust. Safety and Trust* is not only crucial for human-robot collaboration [37], but also essential to *avoid anxiety* of working with a collaborative robot. Landi et al. [35] mentions that many governmental and technical regulations have been made to ensure safety in human-robot collaboration. In addition, during our study, participants felt quite safe around the robot and trusted that the robot will not harm them.

Inspiration is an interesting UX goal in the context of human-cobot interaction as it has not been explicitly mentioned for human-robot collaboration or human-cobot interaction prior to our research. However, it complements experiences like *supporting competence [29], stimulation [*3*] [*5*] [*36*] and experience of fluent cooperation [*24*][29].* Hekkert et al. [24] discuss about *resonance* between human and machine, which indicates that user and machine play with each other and inspire each other. Social robots are designed to motivate users to learn new skills in playful manner [2]. However, this method is scarcely seen in humancobot interaction. Inspiring the workers in a playful manner will *support competence* [28] and evoke *stimulation* [36] in human-cobot interaction. The aim of describing scenarios with gamified elements and rewards in Section 4.3 is to make the learning experience enjoyable for the workers [36] and make them feel competent in the field of human-cobot interaction [29]. Thus, learning about the cobot will evoke *the experience* of *fluent cooperation* between human and the cobot.

Accomplishment is extensively observed in games [34] and playful learning context [2] [11] [31], according to our knowledge, this particular UX goal has not been explored in industrial context. However, in our study, we could observe joy and excitement among participants upon *completion* of a task. It would be interesting to explore this UX goal in industrial setting and observe if human workers experience *completion* in humancobot interaction.

To illustrate how interaction designers could utilize the above mentioned UX goals to focus on holistic UX in EDD approach [51], we outline practical scenarios based on the phases of interaction:

*Before Interaction***Scenario: Robot's personality and story.** One practical scenario could be that the robot verbally expresses itself and answers to workers' queries. For example, the cobot can greet the human worker and he/she can ask questions like "how is the cobot doing?", "what is its purpose?", "how does it work?" etc. In addition, the robot can formally introduce itself and tell its story, for example, how was it born and what are its characteristics. Before interaction the human worker can also verbally ask about any technical terms that are used by the interface and the cobot can clarify it verbally. Such conversations before and during the interaction would help the workers accept the cobot as a co-worker rather than a machine [45].

This scenario will not only evoke fellowship among workers, but also reduce their *suffering* caused by confusion and uncertainty, as such the users can easily clarify any doubt by verbally asking the robot. However, these verbal instructions could also be written in simple words for workers who are unwilling to interact with emphatic behaviour during work time.

During Interaction **Scenario: Rewarding the user.** The workers can be motivated to learn about the robot and explore its functionalities with excitement and curiosity by providing meaningful rewards [2]. For instance, the cobots could initiate learning tasks for the workers and provide some praise points for them. Each week, the highest praise point achiever can get appreciation from their superior. In addition, the praise points assigned by the cobot could be displayed in a leader board on an external screen. Depending on the points, the workers can be divided into levels like beginner, intermediate, expert etc. The praise point can be assigned depending on number of goals achieved, for example, "discovering new applications", "performing a task with the least amount of time taken" etc. In addition to *inspiring* the workers, this feature will also help to turn *Exploration and Discovery* into positive experience. *Inspiring* the participants to explore and learn about the robot can turn *discovery* into a fun experience. Moreover, introducing gamified elements, such as reward points and level of expertise, will also evoke *pride* among the workers [12].

Scenario: Viewing intended movement. One scenario for this could be displaying the intended movement of the robot [45]. For instance, after programming the motion of the cobot, it could communicate its motion intent with the workers. This could be done with the help of augmented reality or by creating 2D or 3D visualization. One participant suggested that this issue can also be solved by projecting the cobot's figure on the workspace, which can imitate the cobot's future intent. This will not only ensure *safety and trust,* but also evoke *sense of control* among workers.

*After Interaction***Scenario: Getting feedback from the cobot.** The cobot could, for example, give feedback about the workers performance by showing the number of errors occurred during the task and completion time. This will provide motivation for the workers to learn ways to collaborate efficiently with the cobot. In fact, Chowdhury et al. [12] mentioned how displaying performance score motivated students to learn a new language. The cobot could also provide statistics about the workers' performance over a period to show his/her performance. Nonetheless, any feedback or nonverbal gesture should be provided in a positive way, so that it does not discourage the workers to use the cobot [6].

6 LIMITATIONS

We conducted mainly qualitative user study with 22 participants, thus the data gathered from the questionnaire is limited. However, this is an explorative phase in our research, thus we focused on qualitative data that can provide good insights into a novel topic.

While we explored the user experience and UX goals for industrial use of cobots, we conducted our study in a laboratory environment, instead of industrial environment. Thus, we could not get exposed to the factors, such as noise pollution, that affect human-robot interaction in the industry. Since our target was to understand the needs and experience of novice users, it would be challenging to gather participants who have little or no experience with the industrial robots and systems. Moreover, the university lab simulated the real context to a large extent and hence we can assume that the experiences would be similar as in the real context. In addition, we established these UX goals based on millennials' (born between 1981 and 1996) need. However, millennials are a good sample of target users due to the likelihood of millennials operating new generation cobots in future. Additionally, we evaluated only one robot with one interface. In fact, there are several kinds of robots and interfaces which are used in the industry. In future, we aim to overcome the constraints in this study and explore the industrial environment, other industrial robots and interfaces.

7 CONCLUSION AND FUTURE WORK

In this article, based on the research through design process [59], we identified the user experiences evoked during human-cobot interaction and set four UX goals for it. Moreover, we provided practical scenarios, which would help achieve the identified goals. Such experience goals can help interaction designers to design for pleasurable human-robot interaction for collaborative robots. In addition, designing interactions according to the scenarios will motivate the human workers to form social bond with the robot and learn about it. One of our future aim for the research is to evaluate the suggested scenarios with experts in the field of industrial and collaborative robotics. The idea is to get their feedback on the suggested scenarios and how feasible these concepts are for the industrial environment. Furthermore, we will conduct experiments with target audience based on the most feasible concept to validate the user experience.

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