"How are you today, Panda the Robot?" – Affectiveness, Playfulness and Relatedness in Human-Robot Collaboration in the Factory Context

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Abstract— **The integration of collaborative robots (cobots) is changing manufacturing and production processes in factories. When cobots are designed to be efficient, skillful and safe to interact with, workers can collaborate with them conveniently. As workers often work with cobots intensively, it is crucial to explore the user experience (UX) of cobots. The goal of our research is to explore how factory cobots could be used in ways that support pleasurable worker experiences. We adapted "research through design" (RtD) to conduct exploratory research on novel interactions related to affectiveness, playfulness and relatedness in human-robot collaboration (HRC) using collaborative robot arm, Panda. RtD is a method that utilizes methods and practices of design to produce new knowledge. We conducted an exploratory study with 33 participants to evaluate three HRC storyboards scenarios in two complementary remote workshops. The findings report suitability of affective and playful behavior of cobots in an industrial setting. In addition, we deduced that personality of the robot plays a crutial role in HRC.**

I. INTRODUCTION

Collaborative robots (cobots) have been designed to work in the same space with human workers and are intended to operate at slow speed for the sake of collaboration with humans [1]. It is argued that installation and programming of cobots are easy and thus, workers collaborating with the robot could easily operate the robot without any technical assistance [2]. However, such novel technology could induce anxiety and stress among workers, especially if they do not have any technical background [3]. Such negative experience of the workers could lead to decreased effectiveness and wellness at work and it is, therefore, essential to consider the user experience (UX) of human-robot collaboration (HRC) in the industrial settings while designing interactions for cobots. So far, safety is the most explored UX aspect in this research area [1], [4], however, there are additional UX aspects evident in HRC [5], [6]. According to Chowdhury et al. [5], interaction designers should consider designing for user experiences like fellowship (forming a bond between human and cobot), accomplishment (feeling of being accomplished and able to achieve goals), inspiration (motivated to work with the cobot) and safety and trust (feeling safe and trusting the robot's intention for fluent collaboration) for the formation of pleasurable user experience in HRC. Sauppe et al. [7] reported that cobots playing certain roles are considered to be team players, which is essential to evoke fellowship and trust. The aim of this article is to investigate what kind of interactions could be designed to evoke the prior-mentioned experiences and their suitability in the industrial context. To design the interaction, we adapted three theoretical concepts: affectiveness, playfulness and relatedness. Based on the theoretical concepts, we developed three storyboards for HRC and conducted two workshops to evaluate scenarios designed according to the novel interaction elements to answer the following research questions:

1) What kind of affective and playful interactions could be suitable for collaborative robots?
2) What kind of role could the robot play to support relatedness between human and robot co-workers?

II. RELATED WORKS

In this section, the concepts of affectiveness, playfulness and relatedness are discussed, how they are utilized in HRC, and how they are relevant in our context.

A. Affect in Human-Robot Collaboration

The word affect describes a spontaneous response of the body to an experience [8]. It is influenced by emotion (e.g., sadness, fear, anger) and physiological responses (e.g., electrodermal and cardiovascular) [9]. On the other hand, computers, or embodied agents such as robots, do not perceive or portray affect such as human beings. They compute affect to respond to, raise or influence emotion, which is known as affective computing [10]. There has been extensive research and implementations of affective computing for social robots [11], which can express affect through gestures, voice, gaze, facial expressions, etc. [12].

In the context of cobots, there have been few research works about how and why affective behaviour might be useful. Cobots, such as Baxter by Rethink Robotics have used affective and social expressions to communicate with the user [13]. Rethink Robotics [14] and Workbot from pi4 considered behaviour and body language of the robot to make the robot affective [13]. The cobots look around the surrounding before performing a pick and place task to warn the user about its potential movement. On the other hand, Sauer et al. [15] investigated zoomorphic gestures for Franka Panda robot. They developed both zoomorphic (based on dog body language) behaviour and abstract (developing new self-contained gestures) gestures. They used a robot arm to mimic specific body parts of the dog and goal-based gestures inspired from a dog's behaviour. One of their developments was to inspire the worker to participate in the task, which was adapted from the dog's behaviour to encourage the human to play.

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In our context, affective expressions could be used to evoke fellowship, safety and trust [5] in HRC by designing social interaction between human and cobot. The elements of social interaction can be natural voice, facial expression, gestures, postures, etc. [12]. According to Follet et al. [13], social skills like behaviour and body language, can be designed for collaborative robots to evoke perceived safety and trust among users. On the other hand, Sauppe et al. [7] found that Baxter's affective facial expression helped the factory workers to form a social bond with the robot, evoking fellowship, or companionship. Terzioğlu et al. [16] investigated the role of gaze and breathing in HRC and concluded that it had a positive impact on *social presence, perceived enjoyment, and likeability*. They implemented gaze, posture and breathing cues to provide an animal like characteristic for the robot. Since it will be a novel and promising approach to design social interaction elements for collaborative robots, we aim to achieve this by designing affective expressions for cobots.

B. Playfulness in HRC

Elprama et al. [17] stated that social interaction may not be enough to support factory workers' willingness or inspiration to work with the robot. One way to inspire the workers and make them feel accomplished in their task is by adding playful elements during the interaction [18]. Playfulness is a pleasurable mood state where someone can be spontaneous, expressive, and creative [19]. The playfulness concept has been derived from playful behaviour in children [18], [19]. Children are inspired and intrinsically motivated to play and sometimes create own rules and games while playing with peers [19]. Although playfulness and playing games are often associated with each other, playfulness is a broader aspect in human behaviour as it can be observed even in daily activities of humans [20]. According to Lucero et al. [20] playfulness is often spontaneous and rewarding for humans, thus they are often less stressed in playful states.

Social robots seem to inspire and persuade people to achieve their goal by encouraging them to play [21] [22]. Ahtinen et al. [21] mentioned that children were inspired to learn and answer to the Nao robot's questions to get rewarded. Chowdhury et al. [23] observed people setting language learning goals after participating in a "language quiz" with Pepper robot. In addition, there are many instances where social robots encourage humans to play in the context of teaching, city guidance, and ice breaking [21], [22], [24].

To our best knowledge, playful interactions to inspire factory workers to work with cobots has not been explored. Therefore, it would be a novel approach to investigate whether cobots could engage factory workers in playful mood, inspire them to collaborate with the cobot and evoke a sense of accomplishment by providing appropriate rewards.

C. Relatedness in HRC

Another concept, which could be considered in designing social interaction for robots, is relatedness. Relatedness is one of the three universal psychological needs that are essential for wellbeing and health, the need of being connected to others [25]. Social relationships provide people with a sense of such relatedness [26] and they could be the key element of meaningful work in HRC [27]. If cobots could develop social interaction capabilities and humans were capable to perceive and respond to them [12], both would develop better understanding towards each other [27]. Such mutual understanding could evoke a sense of fellowship or companionship among the factory workers. Cobots have already been considered as team players in many contexts [7], [13] and have been assigned different roles, such as grandchild [7], buddy [5], or pet [15]. Sauppe et al. [7] reported that factory workers often referred to Baxter robot as their son, grandchild or assigned a role to it and were cordial to the robot.

In the context of HRC, we aim to investigate what role the robot could play to support relatedness between human and cobots. Determining the role of the robot could also guide us to develop social and non-verbal gestures for cobots to support HRC and evoke fellowship among the workers.

III. Methodology

The research approach in this study is *Research through Design* [28], in which scientific knowledge is created through studying novel design concepts and evaluating them with potential users. We used the storyboarding technique [29] to illustrate the novel interactions we designed for HRC. A storyboard is a short graphical presentation of a story. Storyboards are used to visualize novel features and interaction to demonstrate how they might work in the early development phase. The storyboard experiment will be one of the video experiments [30]. We developed three storyboards based on the concepts described in the Related Works (see Section II).

In order to evaluate our concepts as storyboards, we conducted two complementary workshops with 33 participants. The first workshop was conducted with 15 interaction design and robotics students who would potentially work as robot developers and designers. The second workshop was conducted with 18 professionals who were either using or considering to use cobots in their workflow. In the workshops, we discussed about the storyboards, their feasibility, contextual aspects and alternative solutions which might be suitable in our context. In this section, we describe the design and evaluation of the storyboards.

A. Designing the Storyboards

In the first phase of designing the storyboard, we decided to develop interaction design elements based on three theoretical concepts: affectiveness, playfulness and relatedness (see Section II and Table I). Interaction design elements are a conceptual set of components which aid interaction designers to illustrate the interaction between users and the technology [31]. In our context, we established interaction design elements to exhibit the novel interaction between human and cobot in industrial settings, as described in Table I. Based on this, we developed three storyboards. In the scenarios, we depicted an industrial setting, where the robot

TABLE I: Interaction design elements, related concepts and experiences for the three storyboards

Storyboard	Interaction design elements	Theoretical concepts: Affectiveness	Theoretical concepts: Relatedness	Theoretical concepts: Playfulness	Experiences: Fellowship	Experiences: Safety	Experiences: Trust	Experiences: Inspiration	Experiences: Accomplishment
#1	Cobot telling its story	✓	✓		✓	✓	✓		
#2	Robot showing its emotion	✓	✓		✓				
	Playful tutorial			✓				✓	✓
	Positive feedback/appraisal		✓				✓	✓	
	Reward			✓					✓
#3	Cobot learning from the worker		✓				✓	✓	✓

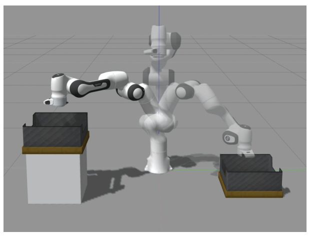

Fig. 1: Image of the Panda robot operating. In this picture, Franka Panda is performing a pick and place task.

performs pick and place tasks. We adapted Franka Panda cobot[1] as the robotic platform to generate the storyboards. Franka Panda could be manually moving from one position to another and parameters of the destination could then be stored via the web-interface called Desk (see Fig. 1).

In the storyboards, we portray Franka Panda introducing itself to the worker, helping them to learn operating itself, encouraging and appraising them for their achievements and encouraging them to teach Panda new skills. Below is the description of each storyboard:

Storyboard 1 - Introduction to Franka Panda: We illustrate the first interaction of the worker and Franka Panda cobot. During the introductory phase, Panda explains shortly about its background and why it is eager to interact with a human. It describes about safety issues and suggests not to panic if errors occur. Panda gives a verbal description of its behaviour and explains about its "robot happiness index" (see Fig. 2a). Panda explains how the progress of the worker could impact the happiness index.

The storytelling behaviour of Panda could be perceived as social interaction with the workers and it expresses *affectiveness* as well as *relatedness* (see Table I). The background story of Panda would help the workers to know about the it, which might help the workers empathize with Panda and accept it as a team member. Link to storyboard 1: `https://youtu.be/MEZCrwdslO8`

Storyboard 2 - Tutorials with Franka Panda: One of the features of Franka Panda cobot is that it can be manually moved to the position of a desired location. In this tutorial Panda helps the worker to learn how to move its arm via a playful tutorial. The aim of the tutorial is to teach the workers to move Panda manually. In addition, Panda would provide positive feedback and hints to improve the worker. We also designed a "robot happiness index" to express the Panda's emotion and affective behaviour. There would be a visible change in the robot's happiness index to indicate the workers' performance (see Fig. 2b and Fig. 2c).

Panda would also challenge the worker in a friendly way to complete certain number of tasks without any error. As a reward Panda would display an achievement board with number of stars collected (1 star for each error-free task) (see Fig. 2d).

This tutorial is designed for *playfulness* (see Table I) and to provide an opportunity to the workers to "play" with Panda. The feedback and rewards are intended to encourage the workers to interact with Panda. Link to storyboard 2: `https://youtu.be/wlMEMTyfHKs`

Storyboard 3 - Teaching Franka Panda: In this storyboard we depict a scenario where both human and cobot learn something from each other. Panda guides the human to operate itself using verbal commands (see Fig. 2e). Furthermore, Panda suggests the human to teach new skills by moving it manually and feeding more voice commands (see Fig. 2f). The worker could also follow how much Panda has learned from her from the "Achievement with Panda" scoreboard.

Teaching the panda and collaborating with it might evoke a sense of relatedness to the worker (see Table I). If the workers teach verbal commands and skills convenient for them, it will help Panda develop verbal interaction capabilities perceivable to humans. It would help the human to communicate with Panda in his own language and build a social relationship with it. Link to storyboard 3: `https://youtu.be/zVVdca_WyN4`

B. Evaluation of the Storyboards

After developing the storyboards, we demonstrated and evaluated our ideas with potential users of cobots. The user study was part of a online workshop called "Human-Robot Interaction in Industry - A Futuristic Approach". The workshop was conducted in two parts and was designed for two separate target user groups. Prior to each workshop, we asked for permission from the participants to record the discussion sessions and assured them all the data will be

[1] `https://franka.de`

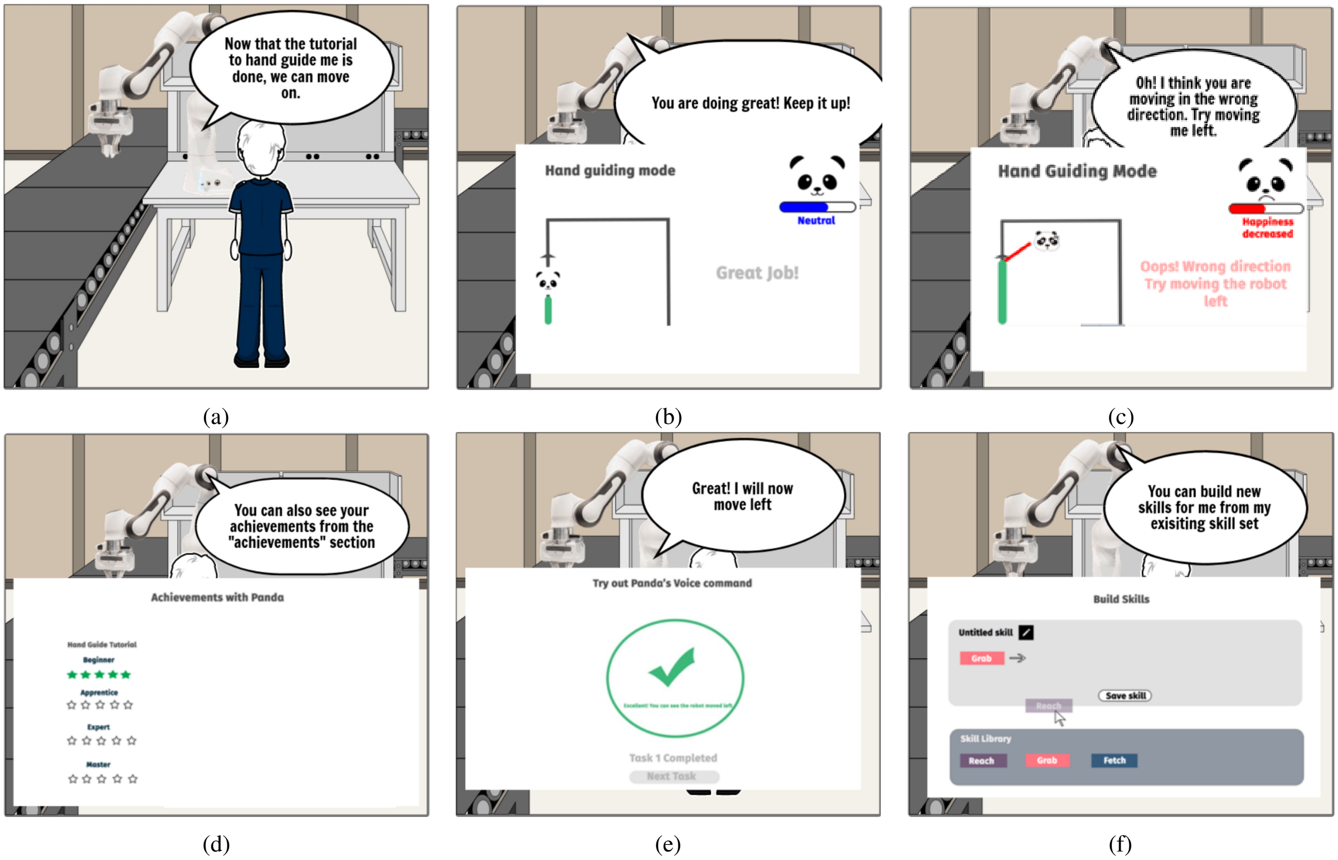

Fig. 2: Illustrations of the different storyboards and their content. Storyboard 1 is depicted in (a) and introduces the Franka Panda robot by voice interaction. Storyboard 2 is depicted in (b), (c) and (d) and addresses different tutorials for interaction; expression of emotion and behavior (b) and (c), and rewards (d). Storyboard 3 is depicted in (e) and (f), and introduces voice commands (e) and robot skill teaching (f).

anonymised and will be stored for 2 years. Furthermore, we added that the data will be used for scientific research purposes only.

The first workshop was two hours long and was arranged for two graduate (MSc. level) courses (”Collaborative Robotics” and ”User Experience in Robotics”), held in Tampere University. 15 students (see Table II) attended the workshop and all the students were either Masters or Doctoral level students. Although many students were not familiar with Franka Panda robot, they have at least interacted with some kind of robots, for example social robots. The workshop was conducted in three stages: 1) Introduction to UX and collaborative robotics, 2) online demo of the state of the art, 3) discussions on the storyboards in multidisciplinary teams of UX and collaborative robotics students. The first stage involved a set of presentations about collaborative robots, UX, importance of UX, and its relevance in the context of HRC. The aim of the presentation was to provide a common insight among all participants. In the next stage, we presented online demonstrations of cobots and features related to UX. For the third stage, we divided the participants into teams to discuss the storyboards. The team discussions were approximately one hour long. Each team facilitator presented the storyboard and encouraged the participants to take part in the discussion. The teams discussed about the suitability of the concepts in industrial settings, contextual issues that might arise and suitable alternatives (if necessary). The workshop ended with a wrap up of their discussion and findings. The second workshop was arranged for SMEs (small and medium-sized enterprises) who involve or wish to involve cobots in their workflow. 18 participants (13 male and 5 female) took part in the workshop and the majority of the participants were either UX designers or software engineers.

TABLE II: Participant’s background for workshop 1

Description	Number of Participants
Gender	Male (9) Female (3) Prefer not say (3)
Age	23-27 (6) 28-32 (3) Prefer not say (6)
Robots they interacted with	Social robots (6) Collaborative robots (9)

The second workshop followed a similar structure to the first one, however, a detailed presentation on cobots and their usage in the industry was added in the introduction phase. The presentation was targeted towards participants from companies who wish to involve cobots in their workflow or had no previous experience about cobots. The introduction provided them with ideas about how cobots work, and what kind of tasks could they perform in the industry. The purpose of the detailed presentation on cobots was to ensure that all participants had similar knowledge on the topic. The online demo session and team discussion sessions were held in correspondence to the first session.

C. Data Analysis and Tools Used

Since the designed interaction elements were novel and at a conceptual stage, our aim was to collect qualitative data from the two workshops and gain knowledge on the perspective of the participants. The qualitative data was transcribed from the recorded workshop discussions and we analyzed the data by using the content analysis method [32]. We went through the recorded sessions and categorized the data under different themes. In total we had 4 predefined themes and 19 emerging themes. The predefined themes were *possible experiences, suitability/feasibility issues, contextual issues, and role of the robot*. Under each predefined theme, we had emerging sub themes. For instance, under the main theme *contextual issues,* we had sub themes like *social issues with the robot, robot pretending to be human, mistrusts, safety concerns*, etc.

We utilized several online tools to conduct the design and evaluation phases. To develop the storyboards, we used an online tool called Storyboard[2]. We conducted the workshop in Zoom application and used breakout room functionality for team discussion sessions. The storyboards were provided in Mural[3] canvas, where the participants went through the storyboards together with the team facilitator, documented their ideas and brainstormed in teams. Finally, we used atlas.ti[4] software for the content analysis of the transcribed sessions.

IV. Findings

In this section, we present our findings related to the research questions (see Section I). We aim to explore the suitability of the affective and playful interactions and role of the cobot to support relatedness in human-robot collaboration based on each storyboard. While the participants in the workshops were discussing about the storyboards, we gathered qualitative data from their discussion. When presenting the findings, we cite the participants' comments along with their codes and gender. The codes of the participants do not contain information about the workshop they attended.

According to our findings, there was a coherence in the feedback of both workshops' participants. The attending students had sufficient knowledge about the industrial settings and discussed similar issues as the participants representing the industrial group. Therefore, we did not segregate the findings of the two workshop participants.

A. Findings Regarding Affectiveness

We designed two interactions which would support for affectiveness in human-robot collaboration: *cobot telling its story* and *cobot showing its emotion* (see Table I).

Overall, participants felt that the storytelling behaviour of the cobot could help the workers trust the cobot, decrease anxiousness and evoke fellowship. "You can trust the robot if you observe for a while" (P7, Female). "People can feel like they are hanging out with their robot buddies" (P2, Male). The participants also mentioned that such social experiences might be interesting for them. "The social sides of such cobot is very important and should be carefully designed" (P4, female), "Personal experience would be memorable for the workers, if there are points they need to remember" (P8, Female).

Next, we discuss the suitability, feasibility and contextual issues raised by the participants and potential solutions suggested by them.

Suitability, Feasibility and Contextual Issues: 10 out of 33 participants raised the issue of a noisy environment in the industry. "It's a really noisy environment in the industry, so you have to make sure the person is not screaming to answer the robot" (P1, Male). Two participants raised concerns that it might not be time economic if the cobot tells its story in one-to-one interaction. Furthermore, they added, "It would make sense if the worker wants to concentrate on the task, instead of chitchat. It would be nice if the robot understands the intent of the person" (P10, Male), "If I have to wait 20 seconds for the robot to finish telling its story, it's not efficient" (P3, Female). One participant added such conversations can put the workers in social situations. "It is a bit socially demanding. If people are around you, you might feel you are performing socialites with the robot" (P5, Female). Five participants agreed that voice without any animated movement or gestures would be unnatural. "It feels weird if the robot is not moving but talking only" (P2, Male). In addition, two participants raised their concerns if they can trust the robot based on what it says. "When the robot says it will stop after collision, I hope it does!" (P5, Male).

15 participants raised their concerns about robot's happiness index. "What is the purpose of the robot's happiness index? If it is for motivating the workers, why not use user's happiness index?" (P14, Male). The participants also raised concerns that the users might not care about the cobot's happiness. One participant mentioned that it might be stressful for the workers to see the cobot sad when something goes wrong. "It makes me sad to be responsible for a robot's happiness. It might be stressful to keep the robot always happy" (P4, Female).

Potential Solutions: There were many suggestions from the participants regarding the noise in the industry.Participants suggested algorithms to reduce the noise production, noise cancellation headphones, building a separate noise cancellation room for the cobot, etc. According

[2]https://www.storyboardthat.com
[3]https://www.mural.co
[4]https://atlasti.com

to the the participants, the voice interaction wsould be a suitable affective behavior if the noise of the environment is controlled and suitable according to factory settings.

Although the participants criticized the cobot's happiness index, they agreed that if the cobot shows "right" affective gesture, it could evoke fellowship among the workers. Five participants suggested that it would be feasible to assign certain personality to the cobot to define emotions and gestures accordingly. "If we want to go deep into this context, the personality of the cobot would depend on what kind of workers we are dealing with" (P2, Male). "...maybe if my robot has a personality based on R2D2 theme, same functions but kind of customized personality" (P1, Male). "In iron man you have seen dummy cobot, when Tony Stark is talking to him and says oh don't touch anything, you would see him turning a bit back..." (P1, Male). One participant mentioned cobots could have humor as their trait. "The robot walked us around the factory and kind of mocked the other robots. It reflected a bossy personality, but it was funny" (P6, Male).

B. Findings Regarding Playfulness

We designed two playful interaction design elements to support human-robot collaboration: *playful tutorial* and *reward* (see Table I).

Participants agreed that the playful approach to teach cobot operation could motivate the workers and such interaction has the potential to evoke curiosity among the workers. "People will be okay to make mistakes. They will not feel judged" (P12, Male). However, participants were concerned if such playful tutorial is suitable for long-term interaction.

The participants agreed with the rewarding approach of the cobot, however they were unsure of the rewards suitable for factory workers.

Suitability, Feasibility and Contextual Issues: Although the playful tutorial was acceptable and suitable for the industrial context according to the participants, there were few concerns. "Will this be for long term interaction? Because worker might get bored repeating the tutorials every time" (P20, Male). In addition, two participants discussed the rewards related to the tasks. "Are stars valuable for workers?" (P9, Male). "What happens after I achieved all the stars? What's next?" (P21, Male).

Potential Solutions: According to the participants, the playful tutorial is suitable only for a training period. This would inspire them to work with the robot and learn necessary skills within a certain period.

The participants suggested to add music, smileys and feedback as reward. "Add bonus for mistake free day... one day a streak, 10 command a streak" (P2, Male). "You can design different shades of smiles as feedback for the user's performance" (P12, Male).

C. Findings Regarding Relatedness and Role of the Robot

We designed four interaction design elements, which would evoke sense of relatedness among participants: *cobot telling its story, robot showing its emotion, positive feedback/appraisal and cobot learning from the workers.* These elements also helped us determine the role of the cobot expected in industrial settings.

Three participants mentioned that teaching the cobot might evoke a sense of superiority among workers. One participant mentioned that it felt like the worker is nurturing the cobot. Participants also mentioned that if two or more workers are involved in collaborative teaching, a "community of practice" might develop between people and they learn from each other. Thus, it would also enhance human-human interaction in the industry and might evoke a sense of community/belongingness among the workers (P4, Female).

Since we already described the issues and solutions regarding cobot telling its story and robot showing its emotion, in this section, we are going to discuss about participants' feedback regarding feasibility and contextual issues concerning *appraisal* from the robot and *cobot learning from its workers*. In addition, we discuss about the role of the cobot in the industrial settings.

Suitability, Feasibility and Contextual Issues: Two participants were worried if the cobot could perceive the parameters related to motion when the worker is teaching it. "Move left, how much?" (P2, Male). They felt that it would be too much information for the worker to provide for the cobot by voice. "I think it is better to operate the robot using traditional interfaces in this case. It is too much cognitive load for the user to mention everything" (P1, Male). One participant added "Teaching the robot doesn't necessarily make the worker feel accomplished" (P14, Male). Another participant argued that it might encourage the worker to see that the cobot is learning simultaneously.

One participant mentioned that the appraisals should be carefully designed. "Watching me grow you will feel accomplished" might be too much pressure" (P4, Female). 20 participants agreed that it should not behave too much like humans while praising the user. "The way the robot is talking, I think its too much emotional and too much like humans" (P1, Male). Moreover, one participant mentioned that if the robot's behaviour is close to human, the expectation of the workers will be high.

Potential Solutions: Few participants suggested that it is feasible to move the cobot using Oculus joystick in VR (virtual reality) and somehow send the command from VR. "Maybe if you replace the voice interaction with VR interaction, it would be easier. The user can simulate the robot in the virtual environment and send command to the robot virtually" (P2, Male).

1) Role of the Cobot: From the participants' feedback, we explored what kind of role is suitable for the robot to support relatedness in HRC. As mentioned earlier in this section, participants agreed that the robot should not portray human personality.

Seven participants agreed that the cobot should have a unique personality. One participant compared the robot's personality to his pet. "I would feel related to the robot if it behaves like my pet, rather than teaching me how to perform the tasks" (P14, Male). Another participant mentioned that, humor could be added in the personality of the robots.

Based on the participants' feedback, we deduce that the cobot's role is to support humans in collaboration tasks. However, it should have an individual personality and evoke pleasurable UX in HRC. The cobot's personality would depend on the context of the industry, but it should be supportive, friendly, and non-human like.

V. Discussion

In this section, we discuss our findings regarding the storyboards and role of the cobot in the industrial settings in light of previous literature.

A. Affectiveness, Playfulness and Relatedness

Although voice interaction has been used in several contexts for robots [21], [22], [24], it should be carefully designed in the industrial settings. In HRC, researchers explored the use of voice commands to control robots [1], [4], [33]. Pires et al. [33] had used headphones in his research to give commands for the robot. Similar aspects were discussed during our workshops. Some participants mentioned noise cancellation headphones to reduce noise interference during affective voice interaction. However, according to the participants, having a conversation with the robot was demanding in the industrial settings. Sauppe et al. [7] acknowledged the need of affection in the industrial settings and stated that workers expect answers from the robot while talking to it. However, the workshop participants discussed that it might not be suitable for all scenarios. Such conversation might put workers in social situations and induce anxiety if the robot is not capable to understand it. In addition, if the robot acts human-like with conversation capabilities, it might intimidate the workers. The workshop participants concluded that *non-verbal gestures* to respond to voice commands and *assigning certain personality* for the robot would be suitable in industrial contexts.

The workshop participants discussed that a "robot happiness index" might not be enough to support for affectiveness. In fact, it might cause stress among workers in the process of making the robot happy. Robot's happiness index is a novel approach in HRC, however, Sawyer robot uses gaze to update the users about its current status [13]. Such gaze interaction somehow reflects the robot's emotion and evokes a sense of affection among factory workers [13], [16]. Workshop participants referred to such subtle use of non-verbal gestures and mentioned it would be appropriate for industrial settings. We deduced that assigning a certain personality to the robot would help us design appropriate non-verbal gestures in this context. Sauer et al. [15] assigned a pet personality to a robot and designed non-verbal cues according to a certain personality. In conclusion, even though a "robot happiness index" might not be relevant in our context, designing appropriate non-verbal gestures according to the personality of the robot would reflect the robot's emotion and make it affective.

Playful tutorials were appreciated by many workshop participants. Participants mentioned that appropriate rewards could inspire the workers to learn about the robot. However, concerns about robots dominating the workers were raised. Nevertheless, robots have been appreciated and accepted in leading roles such as teaching assistants [21]. It would be beneficial to explore the needs of the users in the context of use before designing for guidance.

Participants agreed that teaching the robot would evoke a sense of superiority among the workers, which is important in this context. The workers should never feel they are dominated by robots as it might induce fear of being replaced [27]. One aspect which was reflected throughout the workshop was the robot having a personality. This could also be beneficial in evoking a sense of relatedness/community/belongingness in HRC. A cobot reflecting different personalities has already been explored [7], [15]. Participants were referring to personalities of robots in movies, for example, R2D2 from Star Wars [34]. In fact, Dum-e robot from Iron Man [35] could be an inspiration to define a unique personality for cobots in industrial settings. According to Mason et al. [35] Dum-e is a robot, showcased in the movie Iron Man, which has its own personality and treats the hero of the movie as a dominating father. Such inspirations from movies could also help define *a unique personality* of the robot to evoke a sense of relatedness among factory workers.

B. Role of the Cobot

The role of the cobot should be very carefully designed in the industrial context. Although humans expect some sort of response while talking to machines/robots [7], the response should vary for different contexts. Designing personalities for cobots could help interaction designers justify what sort of role should cobots play in certain context. In the context of industry, cobots should not try to dominate humans, but follow its orders, in order to help them in the collaboration process. Moreover, it should learn the human's way of working.

C. Limitations

We conducted qualitative research study with 33 potential users of cobots to provide a good insight on suitability of the novel interaction elements. Thus, no quantitative data was gathered.

We evaluated our novel interaction elements with potential users instead of factory workers. Thus, we could not evaluate our interaction elements in authentic context. However, it provided a clear picture of what the potential future cobot users are expecting in this context. In addition, we used storyboards to depict HRC scenarios instead of implementing the interactions on a physical cobot. In human-computer interaction, storyboards are often used to portray how users might interact with novel technologies. Since we designed novel interaction techniques, the storyboarding technique was suitable to understand the suitability and feasibility of the scenarios in this context.

VI. Conclusion

In this paper, we presented a study of human-cobot interactions in industrial settings based on three theoretical concepts: affectiveness, playfulness and relatedness. We adapted these theoretical concepts to evoke fellowship, inspiration, accomplishment, safety and trust in human-robot collaboration. We designed interaction elements and created three storyboards to portray those. In order to evaluate the storyboards we conducted two complementary workshops with students and industry professionals. According to our findings, these interaction design elements have the potential to evoke fellowship, inspiration, trust and sense of superiority among factory workers. Voice interaction could be designed for affectiveness, however, designers should carefully consider the context of work. Similarly, playful tutorials should be well thought out before implementation. However, a cobot's happiness index is not appropriate for the industrial context and might induce cognitive load among workers. Alternatively, cobots could communicate with gestures and cues associated with its personality to show affection. The cobot should play a supportive and friendly role to evoke a sense of relatedness in human-robot collaboration. If interaction designers could design suitable personality, non-verbal gestures and social cues for cobots, it may support for affectiveness and relatedness in the industrial setting and will help the workers to form a bond with the robot. In addition, playful tutorials should be carefully designed in this context. In the future, we will focus on developing suitable personalities, non-verbal gestures and social cues for cobots in the industrial settings. In addition, we will evaluate the prior mentioned aspects in authentic context, i.e, with factory workers in a factory setting.

References

[1] I. Maurtua, A. Ibarguren, J. Kildal, L. Susperregi, and B. Sierra, "Human–robot collaboration in industrial applications: Safety, interaction and trust," *Int. J. Adv. Robot. Syst.*, vol. 14, no. 4, pp. 1–10, 2017.

[2] M. Peshkin and J. E. Colgate, "Cobots," *Industrial Robot*, vol. 26, no. 5, pp. 335–341, 1999.

[3] J. Kildal, A. Tellaeche, I. Fernández, and I. Maurtua, "Potential users' key concerns and expectations for the adoption of cobots," *Procedia CIRP*, vol. 72, pp. 21–26, 2018.

[4] V. Villani, F. Pini, F. Leali, and C. Secchi, "Survey on human–robot collaboration in industrial settings: Safety, intuitive interfaces and applications," *Mechatronics*, vol. 55, pp. 248–266, 2018.

[5] A. Chowdhury, A. Ahtinen, R. Pieters, and K. Vaananen, "User experience goals for designing industrial human-cobot collaboration: A case study of franka panda robot," in *Nordic Conf. on Human-Computer Interaction*, 2020, pp. 1–13.

[6] V. Lotz, S. Himmel, and M. Ziefle, "You're my mate–acceptance factors for human-robot collaboration in industry," in *Int. Conf. on Competitive Manufacturing*, 2019, pp. 405–411.

[7] A. Sauppé and B. Mutlu, "The social impact of a robot co-worker in industrial settings," in *ACM conf. on human factors in computing systems*, 2015, pp. 3613–3622.

[8] B. Massumi, *Movement, affect, sensation: Parables for the virtual*. Durham, NC: Duke University Press, 2002.

[9] I. B. Mauss and M. D. Robinson, "Measures of emotion: A review," *Cognition and emotion*, vol. 23, no. 2, pp. 209–237, 2009.

[10] R. W. Picard, *Affective computing*. MIT press, 2000.

[11] O. C. Görür, B. Rosman, F. Sivrikaya, and S. Albayrak, "Social cobots: Anticipatory decision-making for collaborative robots incorporating unexpected human behaviors," in *ACM/IEEE Int. Conf. on Human-Robot Interaction*, 2018, pp. 398–406.

[12] C. Breazeal and B. Scassellati, "Robots that imitate humans," *Trends in cognitive sciences*, vol. 6, no. 11, pp. 481–487, 2002.

[13] J. Follett, *Designing for emerging technologies: UX for genomics, robotics, and the internet of things*. O'Reilly Media, Inc., 2014.

[14] C. Fitzgerald, "Developing baxter," in *IEEE Conf. on Technologies for Practical Robot Applications (TePRA)*, 2013, pp. 1–6.

[15] V. Sauer, A. Sauer, and A. Mertens, "Zoomorphic gestures for communicating cobot states," *IEEE Robotics and Automation Letters*, vol. 6, no. 2, pp. 2179–2185, 2021.

[16] Y. Terzioğlu, B. Mutlu, and E. Şahin, "Designing social cues for collaborative robots: the role of gaze and breathing in human-robot collaboration," in *ACM/IEEE Int. Conf. on Human-Robot Interaction*, 2020, pp. 343–357.

[17] B. Elprama, I. El Makrini, and A. Jacobs, "Acceptance of collaborative robots by factory workers: a pilot study on the importance of social cues of anthropomorphic robots," in *Int. Symposium on Robot and Human Interactive Communication*, 2016.

[18] S. Ray-Kaeser and H. Lynch, *12 Occupational Therapy Perspective on Play for the Sake of Play*. De Gruyter Open Poland, 2017, pp. 155–165.

[19] J. N. Lieberman, *Playfulness: Its relationship to imagination and creativity*. Academic Press, 2014.

[20] A. Lucero and J. Arrasvuori, "Plex cards: a source of inspiration when designing for playfulness," in *Int. Conf. on Fun and Games*, 2010, pp. 28–37.

[21] A. Ahtinen and K. Kaipainen, "Learning and teaching experiences with a persuasive social robot in primary school–findings and implications from a 4-month field study," in *Int. Conf. on Persuasive Technology*, 2020, pp. 73–84.

[22] N. Beheshtian, K. Kaipainen, K. Kähkönen, and A. Ahtinen, "Color game: a collaborative social robotic game for icebreaking; towards the design of robotic ambiences as part of smart building services," in *Int. Academic Mindtrek Conference*, 2020, pp. 10–19.

[23] A. Chowdhury, A. Ahtinen, and K. Kaipainen, ""the superhero of the university" experience-driven design and field study of the university guidance robot," in *Int. Academic Mindtrek Conference*, 2020, pp. 1–9.

[24] K. Kaipainen, A. Ahtinen, and A. Hiltunen, "Nice surprise, more present than a machine: Experiences evoked by a social robot for guidance and edutainment at a city service point," in *Int. Academic Mindtrek Conference*, 2018, pp. 163–171.

[25] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being." *American psychologist*, vol. 55, no. 1, p. 68, 2000.

[26] K. M. Sheldon, A. J. Elliot, Y. Kim, and T. Kasser, "What is satisfying about satisfying events? testing 10 candidate psychological needs." *Journal of personality and social psychology*, vol. 80, no. 2, p. 325, 2001.

[27] J. Smids, S. Nyholm, and H. Berkers, "Robots in the workplace: a threat to—or opportunity for—meaningful work?" *Philosophy & Technology*, vol. 33, no. 3, pp. 503–522, 2020.

[28] J. Zimmerman, J. Forlizzi, and S. Evenson, "Research through design as a method for interaction design research in HCI," in *ACM Conf. on Human Factors in Computing Systems*, 2007, pp. 493–502.

[29] K. N. Truong, G. R. Hayes, and G. D. Abowd, "Storyboarding: an empirical determination of best practices and effective guidelines," in *Conf. on Designing Interactive systems*, 2006, pp. 12–21.

[30] M. Lohse, M. Hanheide, B. Wrede, M. L. Walters, K. L. Koay, D. S. Syrdal, A. Green, H. Huttenrauch, K. Dautenhahn, G. Sagerer *et al.*, "Evaluating extrovert and introvert behaviour of a domestic robot—a video study," in *RO-MAN 2008-The 17th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 2008, pp. 488–493.

[31] D. Saffer, "The elements of interaction design," May 2006. [Online]. Available: https://www.uxmatters.com/mt/archives/2006/05/the-elements-of-interaction-design.php

[32] Y. Zhang and B. M. Wildemuth, "Qualitative analysis of content," in *Applications of social research methods to questions in information and library science*, B. Wildemuth, Ed. Westport, CT: Libraries Unlimited, 2009, pp. 308–319.

[33] J. N. Pires and A. S. Azar, "Advances in robotics for additive/hybrid manufacturing: robot control, speech interface and path planning," *Industrial Robot*, vol. 45, no. 3, pp. 311–327, 2018.

[34] G. Dudek and M. Jenkin, *Computational principles of mobile robotics*. Cambridge university press, 2010.

[35] H. Mason, "Chosen one of the day: Tony stark's sassy robot dum-e," Nov 2019. [Online]. Available: https://www.syfy.com/syfywire/chosen-one-of-the-day-tony-starks-sassy-robot-dum-e