Evaluating future automation work in process plants with an experience-driven science fiction prototype

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***Abstract*— This paper introduces a video-illustrated science fiction prototype "Remote operator's day in a future control center in 2025" aimed at discovering opportunities for new interaction methods and smart automation for the future factories of Industry 4.0. The theoretical objective was to carry out experience design research in an industrial work context based on explicit user experience (UX) goals. This paper firstly describes how the nominated UX goals were implemented in a video-illustrated science fiction prototype and, secondly, how the prototype was evaluated in two research setups: as video sequences embedded in a Web survey, and as interviews carried out with process control workers. The main contribution is to demonstrate how the science fiction prototyping method can employ video-illustration as a means for future-oriented UX research, and how complementary user-centered methods may be used for validating UX goals by means of a science fiction prototype.**

Keywords: component; Industry 4.0; science fiction prototyping, user experience (UX) design; human-computer interaction (HCI); process control work

I. Introduction

In the future factories of Industry 4.0, industrial tasks are expected to become more knowledge intensive and to change the roles of employees [1]. It is anticipated that future workers will, for example, *monitor and supervise autonomous systems with new interaction methods* and that *work tasks will be shared flexibly between automation systems and human workers.* This paper examines the Industry 4.0 concept by means of user experience (UX) design studies explicitly targeted at process control work in future process plants. The UX design research employs the science fiction prototyping (SFP) method that B.D. Johnson originally introduced as a tool for intelligent environment (IE) research [2]. According to Johnson, SFPs are stories grounded in current science and engineering research that are written for the purpose of acting as prototypes for people to explore a wide variety of futures. In this context, the method was shown to be particularly expedient as a design tool allowing the study of alternative, potential designs and illustrating how to interact with emerging, future technologies after the transformation of industrial work.

UX design is receiving growing attention in the development of industrial working environments and services [3]. In the industrial work context, UX has been interpreted as: *"The way a person feels about using a product, service, or system in a work context, and how this shapes the image of oneself as a professional"* [3]. In general, in the work context UX investigations are based on a thorough understanding of what the users want to achieve in their work, and how this could best be supported. For justifying the SFP approach we refer to Forlizzi and Battarbee [4], who have confirmed that stories and storytelling provide a solid basis for experience design. They explain that as a repository of experience, stories contain almost everything required for deep, appreciative understanding of the strengths and weaknesses of a present service, as well as what needs to be redesigned for the future. In the industrial work context, it is important to note that UX design also needs to be in balance with the brand and image of the company and involve the characteristics of the services that are generally valued by its customers.

In the research for this paper, the intended experiences were first pursued by defining explicit UX goals to which the research group and the industrial partner committed. The UX goals were expected to guide the design towards positive experiences and help in communicating important objectives [5]. In the process control context, the objectives related to *the increasingly intelligent automation, new technical possibilities for remote control work, remote presence of workers and new collaboration practices*; i.e. the holistic future control room as an intelligent environment described by its capabilities. Enabling technologies were considered from a wide variety of alternatives, e.g. speech and gesture interaction, augmented reality (AR) and ambient intelligence (AmI).

The nominated UX goals were elicited in an earlier setup by means of a trend analysis of the business, technology and societal trends of the nominated process control domain. The preliminary user study included studies of workers' current experiences of process control work and what kinds of positive experiences they expect to have in the future. Consequently, significant UX goals were defined in a series of multidisciplinary co-design workshops that involved researchers and company partners. This research determined that the primary, higher level UX goal in the process control work context should be "Peace of mind", which was interpreted as: *"The operator knowing what is going on in the production process and how to intervene when needed"*. "Peace of mind" subsequently included the following seven UX goals that guided the final SFP creation:

- Sense of control
- Trust in human-automation cooperation
- Sense of freedom
- Ownership of the process
- Relatedness to the work community
- Meaningfulness of the work
- Success and achievement

The research for this paper has employed the results of the preliminary study, which is not described further here. This paper limits itself to explaining how the nominated UX goals were implemented in a video-filmed science fiction prototype and how the prototype was subsequently used for analyzing the goals with the process plant operators. The experience-driven SFP was dedicated to elaborating and providing meaning for the UX goals, and the iterative work was carried out by a team comprising researchers, company representatives and video production professionals.

The main contribution of the paper is to introduce the outcome of the process: the SFP titled "Remote operator's day in a future control center in 2025", which was created by rigorously following the science fiction prototyping method. The paper has two contributions to the development of the method. The first is to demonstrate how SFP can employ video-illustrated scenes as a formal method of inquiry, and the second is to demonstrate how SFP can be used for validating UX design investigations through user research. With respect to the latter task, the paper emphases the role of reflection, which is normally the final task in the SFP process. This line of work has been introduced earlier, e.g. in [6,7] and the validation of SFPs has earlier been demonstrated in [8,9]. As compared to earlier research, this paper emphasizes the user research results, thus allowing the future process control workers' opinions to be justifiably heard.

II. PROCESS, DATASETS AND METHODS

To support our aim of describing and illustrating the UX goals using the SFP, the design approaches selected were primarily video sequences and, secondarily, interaction demos. The research group considered the means to provide easy delivery of content to the evaluation participants. First, the research group organized a workshop for creating screenplays for six short videos. The videos were then filmed in an interactive collaborative environment that was staged with a set of monitors, wall-sized projected displays and large touchscreens. The video scenes addressed different activities taking place in the imagined future process control environment and illustrated how the activities could be supported with the selected new technologies. Consequently, the six videos were combined as scenes under the SFP "Remote operator's day in a future control center in 2025" that were further evaluated by users.

For evaluating the video-illustrated SFP, two complementary user research setups with expert control room operators and process control workers were established. In the first evaluation setup, the participants were introduced to the SFP via YouTube videos embedded in a Web questionnaire. The questionnaire included a discussion space that was active for a two-month period, in late 2014. In all, 58 experts participated in the Web survey; 16 of whom were active commentators. The participants were selected from among the customer companies of the project's participating company. The participants' background in process control work was diverse, and the domains related to the chemical industry, energy distribution, energy production, food industry, forest industry, manufacturing and nuclear power. The participants had work experience of up to 41 years; all were interested or very interested in new technologies.

The second evaluation setup included interviews conducted in situ in a municipal power plant in a city of 120 thousand inhabitants, in southern Finland (details omitted to guarantee participant anonymity), during October 2015. In addition to seeing the SFP via YouTube videos, the participants were also able to try out speech and gesture control demos. The evaluations included six operators (all male) aged 27–34, who described their occupational titles as: automation manager, process operator, power plant operative, service engineer, automation engineer, and electricity instrument manager. The participants had experience working in the control room environment ranging from 1–7 years; all were interested or very interested in new technologies.

The Web survey consisted of both closed and open-ended questions; the interview setup consisted of a video interview with user analysis [10] and a semi-structured interview [11]. In both groups, the participants assessed six video scenes, one at a time; the main difference between the evaluation setups was that in the Web survey the participants could choose which of the six scenes they wanted to see and comment first. For gaining quantitative data about the UX goals, the users were requested to assess if they could identify with the UX goals, after seeing each video scene, by answering a UX significance questionnaire (using a 5-point Likert scale) specifically created for this project. The users in both research setups answered the same open-ended questions relating to the SFP; in addition, they were requested to analyze the new interaction methods and deliver new ideas. As a final part, the participants were allowed to give overall feedback on the presented future control room environment. The Web survey and interview data were transcribed and qualitatively analyzed.

III. THE SCIENCE FICTION PROTOTYPE

The final SFP video "Remote operator's day in a future control center in 2025" consists of scenes that take place during an operator's shift. The SFP used acted scenes and voice-over explanations and were deliberately aimed to be provocative in order to stimulate discussion between the participants. In the following, a brief explanation of each scene of the SFP and a link to the YouTube videos (presented in Finnish, provided with English subtitles). The scenes introduce routine production supervision, tutoring, preparation for a production change, carrying out the production change, incident management, and a shift change.

A. Production Monitoring

Production monitoring depicts process control operation settings where an operator monitors the status of the situation in the process from a personal workstation (see Fig. 1). The automation system is presented as a proactive, responsive and intelligent partner. The goal is to emphasize the user's sense of freedom and control. These qualities are exemplified through speech-based interactions, which allow the operator to issue commands and enable intelligent agents to monitor the system on behalf of the operator. Link to the scene:

https://www.youtube.com/watch?v=wy-3AwfiY-A

B. Tutoring

This scene focuses on portraying how new interaction technologies enable operators to move freely around the control room and collaborate with one another (see Fig. 2). Their tasks are again supported by the intelligent automation system. An experienced operator is instructing a novice

Fig. 1. Production monitoring.

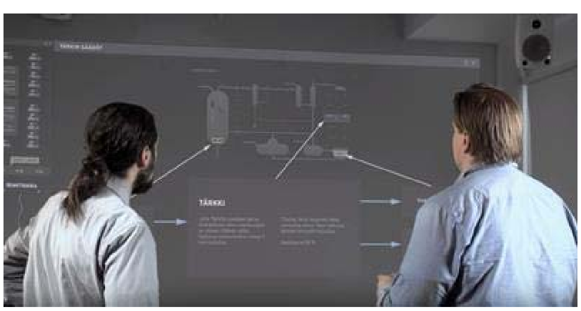

Fig. 2. Tutoring.

Fig. 3. Preparation for a production change.

Fig. 4. Production change.

through a specific part of the production process. The tutoring is performed by gesture and speech interaction through wall-sized displays. Link to the scene:

https://www.youtube.com/watch?v=JRjRJIpwQN8

C. Preparation for a Production Change

Major production changes are procedures that require careful planning to avoid disturbances or unnecessary deviations in production quality. This scene illustrates how the future control room may facilitate collaboration between control room and field personnel through improved situational awareness (see Fig. 3). The control room personnel are going through a production change plan, which they verify by communicating with the field personnel. The technologies include speech-based interaction, large touchscreen displays, field personnel location tracking and live video with augmented reality and 3D elements. Link to the scene:

https://www.youtube.com/watch?v=9rnB96tq_QY

D. Production Change

This scene focuses on the control room operator's tasks during an ongoing production change (see Fig. 4) and the use of internal social media tools. The main focus is on the role of the automation system, which as an active partner supports the human operator in any situation that might arise during the production change. The system is able to predict potential disturbances, record troubleshooting activities, and recommend solutions that the operator can choose. The new technologies relate to speech commands and intelligent, automatic and proactive information collection, prediction and recommendation functionalities. Link to the scene:

https://www.youtube.com/watch?v=guMgYnPoI1Y

Fig. 5. Disturbance control.

Fig. 6. Shift change.

Disturbance Control

The scene illustrates how mobile interaction technologies may be used to access the control system remotely and enable collaboration on- and off-site (see Fig. 5). The scene also illustrates how dialogue with the intelligent system may help operators to manage troubleshooting and disturbances. The system connects to resources and other – even remotely located – operators to assist via a video call. Link to the scene:

https://www.youtube.com/watch?v=8BiNS8dA-xo

E. Shift Change

The final scene portrays opportunities for mobile work (see Fig. 6). The shift change between operators is facilitated by the automation system, which tracks operators via mobile devices. The system ensures that responsibility for the process is seamlessly transferred without the need for face-to-face handover. The new technologies include the use of mobile devices to monitor and control the process, new sensor technologies that recognize and track people, and the intelligent system that monitors operators' activities and facilitates the handover process – without compromising safety or operators' control over the system. Link to the scene:

https://www.youtube.com/watch?v=fz2wyn6Xzgw

IV. Reflection

In Johnson's method, the SFP process concludes with an exploration of the implications and revisiting the lessons learnt. In this paper, the reflection part presents the main findings of the user experience and UX goal evaluations and is therefore more extensive than in regular SFPs. In the following, we present the most important, detailed findings from both evaluation setups. The findings are based on the written (Web survey) and verbal (interviews) discussions that took place after the participants had seen each of the video scenes.

A. Scene 1: Production Monitoring

This scene illustrates the use of speech commands and smart automation system and its user interface. The system was described as supporting freedom of choice, and according to the participants, the presented system certainly provided interesting interaction opportunities. In general, the control room was stated to be pleasant in appearance and the user interface color scheme well composed.

Speech commands were generally seen to be suitable for navigation, opening appropriate views, monitoring of plans and predictions – but not for operations; except in critical situations. The commands for navigation were expected to be very simple and customizable for each operator's preferences. One respondent in the Web questionnaire however speculated critically: "As speech-based interaction doesn't work very well between humans, it could be even worse in communication between humans and machines". The potential for speech recognition errors also aroused some concern. Still, it was believed that the smart automation could be able to pick out some important keywords perceptively from conversations and, accordingly, provide relevant context-aware information.

The smart automation system was considered to make practical work more effortless and efficient, and consequently decrease the probability of human errors in the operation work. The greatest value resulting from the intelligent automation was expected to be achieved in fieldwork. According to the participants, automation is currently not at the level illustrated in the video, and many of the presented tasks are carried out manually. One criticism was that when the automation offered information about alarms in the SFP it only presented the extremes; there was also a need for more comprehensive alarm information. Some participants stated in the interviews that they were used to "fixed" alarm notifications, but even now some preferred to customize them. In the Web survey, some criticized that too much automation might erode the professional skills of the workforce, which, however, could be compensated perhaps by simulation training.

B. Scene 2: Tutoring

This scene introduces gesture control and the use of different types of displays. In general, gesture control and large screen displays were considered suitable for operations and training. Gesture control seemed to work efficiently; especially for zooming in on images and finding trends quickly. One critical interviewee commented that in any of the presented cases he would rather use a mouse. Another critical interviewee remarked that gesture control worked better in the video than in the demo. In general, there was some concern about how the system would react to unintended gestures.

The use of different kinds of displays in the control room was seen to be positive; although it was stated that even currently, some operators prefer printed paper instructions. The use of tablet devices is not yet common in process operations; their use would seem especially appropriate in fieldwork. The trustworthiness of mobile displays was seen to be important for their deployment; namely, that the displays presented up-to-date information. The participants criticized that it was not evident from the scene whether the displays could be used for field operations; this aroused opinions both for and against. Some concerns were related to the fact that in the environment there were often similar devices– e.g. pump and a spare-pump – and their exact location was often of critical importance.

Tutoring seemed to work in the video scene, although some participants commented that the situation is not very different from the present, where new settings are taught by watching them together from a computer screen. It was also considered that a larger display would have been advantageous, especially in problematic situations. One user in the Web questionnaire speculated that: "The best way to guide and rehearse actions for trouble situations would be based on utilizing simulations". For training simulations, the participants highlighted the need for flexible/efficient datamining operations.

C. Scene 3: Preparation for a Production Change

This scene illustrates the use of augmented reality (AR) and 3D models in process control work. Participants commented that the AR features and the detailed 3D model of the plant would provide valuable and useful information for operators and maintenance personnel. An AR interface was considered to be especially valuable in critical situations. In fieldwork one could use AR glasses for observing schemes and diagrams, and this would support the feeling of being in control. 3D images were stated to be valuable in the previously mentioned guidance and simulation situations. One participant speculated: "In a team meeting it [the system] could even offer a possibility to inspect the model together and combine values from the process control system". If the process data were linked to a 3D model that utilizes AR, e.g. for demonstrating local measurements (such as temperature and ventilator states), the improvement on the current state would be enormous. Also, nowadays a lot of information is tacit; maintenance personnel simply follow the pipelines to find the source of a problem.

The participants critically speculated how the system would respond to false notifications and how the presented information was selected from the huge amount of data. One participant mentioned that, as an improvement, AR information could present the location of groups of people working on-site; often there might be dozens of groups in the area simultaneously. The capability of the system to detect the location of individual persons was seen to violate privacy, consequently diluting the UX goal "Sense of freedom". On the other hand, the feature provided valuable information to the control room operators, as: "There was a constant challenge of knowing the accurate situation of fieldworkers; e.g., who is closest to the problematic location". In essence, the scene was considered to support relatedness to the work community.

D. Scene 4: Production Change

The "Production change" scene illustrates automation as an intelligent partner and how colleagues can be accessed remotely via internal social media tools. Automation as an intelligent partner was a well-received concept, especially because currently the list of alerts requires completely independent decisions by the operator. It was however stressed that when the automation acts as a partner, the systems should mainly focus on informing the operator about forthcoming situations and give the operator the authority to decide what to do. In some of the presented situations, the solutions suggested by the system seemed to work well. Participants speculated critically how many alternatives can be shown to an operator – should other alternatives be shown only when the situation is new or infrequent? For inexperienced operators the system was considered advantageous – and even more experienced operators might endorse the possibility of learning new procedures. For some, the scene demonstrated a lack of operator initiative – in process control work there is a constant need to execute personally defined procedures. For advancing the SFP, the participants stated that if the system suggests a process, it should be based on statistics, e.g., on how the last five shifts have operated in similar situations. The system could employ big data and historical statistics from a long time period and thus the operator could better trust the estimations.

The main deviation between responses was regarding the use of social media, with some considering this unsuitable for professional process control work. One participant, however, speculated that this might represent the viewpoint of only some 5–10% of operators, with younger personnel being more open to social media use. Another participant reported that the use of social media (as a separate system) had been investigated in another plant and was rarely used. Nevertheless, it was reflected that social media might offer a means of learning from the tasks and actions of other operators. Some encouraged the use of social media in more of a diary-keeping context: "[T]he system could create a log of definite alterations and tasks in the process; more trivial data could be handled as a group of information".

E. Scene 5: Disturbance Control

This scene illustrates real-time access control and remote communication. Real-time access control and location information were considered useful from the safety point of view. Remote communication was considered important, especially when the distance between locations was extensive. There was, however, criticism that in the SFP none of the operators or maintenance personnel went to the actual location to verify that there really was a problem; "Having an alarm is only part of the problem", they stated, "There is a need for some personnel in the field, all the time". Based on the video scene, the participants highlighted that contacting different experts seemed to be a practical solution: it advances the idea that "the portable device is carried around even during the lunch hour". Contacting a person through remote video communication was considered helpful, especially in the quiet hours (e.g. during weekends), as it allows displaying the live video feed to personnel who are not on duty. The participants highlighted that a person should not, however, have to be alert and available all the time.

In this scene the automation was illustrated as being highly advanced (as compared to the current situation) and this led to considering that the system would contain a huge amount of data. The justification for increasing the level of automation was stated to be that in the control room environments similar situations arise all the time. In disturbance control an essential concern was that the data was up to date. For better facilitation of this, the system should analyze earlier scenarios and process descriptions and find similarities. It was criticized that the current system does not include analogue devices and local meters; it was advised that these would also have to be included in the system. It was pointed out that the license to operate certain machinery is only with the operators, but in some cases there would certainly be a need for sharing responsibilities (e.g. in emergency situations) and then the system might allocate work, e.g., based on the operators' work experience.

F. Scene 6: Shift Change

This scene focuses on security issues and shift briefing. Shift change reports were automatically generated, which was stated to be a very useful feature. According to the operators, the real-world problem was the huge amount of operations during a shift. It was anticipated that, especially in new process plants, the amount of data would become unbearable. The participants speculated about how, in general, the system selects the main operations and actions during a shift. They highlighted that the system should not be left to decide that alone; at least the operator or the manager should make the final confirmation about the shift briefing.

Regarding personnel identification, the participants reported that fluent identification was very important, as currently all the software is password protected. Otherwise, security issues were seen to be more important at the plant entrance, as unauthorized persons rarely have access to a control room. The participants speculated how the identification of multiple personnel influenced the system. They severely criticized that the control room was left unoccupied; this should never happen in current or future control rooms. The participants also criticized that there was no real face-to-face communication, and requested that the system should support human-human communication, especially during critical situations.

G. New Ideas

After seeing the SFP, the participants were requested to express and elaborate on their own opinions, expectations and new ideas aroused by the future concept. Customization – e.g., setting personal alarm limits or personal desktop settings (colors, stroke thickness, scaling possibilities) – was in several responses described as a useful feature. One participant explained: "As the number of displays increases all the time, there is a need to personalize their layouts and, for example, combine trends in different ways. The settings for each individual operator should further be transferable to different devices (e.g. portable tablets). Also, the station in the control room should automatically be adjusted based on identification of the user. The same user could also create several profiles for different situations (such as ramp-up, ramp-down, etc.)". Another participant explained that these customizations could be retrieved by voice commands.

One participant described that in the context of troubleshooting (in the paper machine environment): "It would be remarkable to receive data from the automation system to support what you see and sense in the environment". In many responses, new ideas were stimulated by sequence 3, "Preparation for a production change", regarding video communication/camera surveillance of field workers. The participants speculated on different camera-related solutions that could benefit their work. In the same scene, the virtual 3D model was suggested to be used as an interface with which operators could point at and select physical objects. Furthermore, gamification was mentioned as having a strong role in the future for motivating users. The participants speculated that the gamified features could be exploited in tutoring, simulation and when introducing new tools. Some would be willing to use these features also in fieldwork; in situations when the teams are competing against each other.

H. Speech and Gesture Interaction Demos

Participants in the power plant interview were introduced to a speech and gesture interaction demo, as the possibility for personal experience was considered important when assessing new interaction techniques. The participants were given this opportunity as the last part of the evaluation so that their experience with the prototype would not affect their feedback on the videos. The testing was semi-structured and the included tasks were implicit.

The prototype was implemented using Microsoft Kinect and Microsoft Speech Recognition. A wireless clip on a microphone attached to the user's clothes was used for the speech input. The speech and gesture prototype was built on top of an existing process control system and, consequently, it did not exactly match the interactions seen on the video-illustrated SFP, neither visually nor functionally. The prototype enabled window and view manipulation; participants could point at windows using hand gestures and using an on-screen pointer, grab and move windows by closing a pointing hand into a fist, resize windows by grabbing with two hands, close and resize windows with speech, and point at and change views and open new ones by using speech commands. The actual process control operations were omitted from the supported functionality.

Participants' feedback on the prototype varied greatly depending on how the system operated at the time. Speech recognition rates, in particular, varied from unusable to almost perfect between sessions. The reason for the failures in operation related to a badly placed microphone, e.g., talking too close, so that the voice distorted. The limited precision of the permitted hand pointing was also considered a restriction; particularly since it was operating a system that was designed to be used with a mouse. Still, for many participants the concrete, working example of speech and gesture control provided confidence that such new interaction techniques could be part of a future control room. In particular, speech recognition was seen to have more potential than in the cases presented in the videos. Having direct access to a large number of screens was considered efficient and potentially useful even as part of a traditional desktop interface.

TABLE I. MEAN RESULTS OF THE UX GOAL QUESTIONNAIRES. THE SIX SCENES OF THE CONCEPT VIDEO (TOP ROW) ARE EACH DIVIDED IN TWO CELLS, PRESENTING THE MEAN RESULTS OF THE WEB-QUESTIONNAIRE (LEFT) AND INTERVIEWS (RIGHT). THE SUM VARIABLES WERE CALCULATED USING A FIVE-LEVEL SCALE (5 = STRONGLY EXPERIENCING THE UX GOAL – 1 = STRONGLY DISAGREEING WITH THE UX GOAL). BEST SCORES ARE MARKED IN BOLD.

UX Goal	**Scene 1**		**Scene 2**		**Scene 3**		**Scene 4**		**Scene 5**		**Scene 6**	
	N=10	*N=6*	*N=8*	*N=6*	*N=7*	*N=6*	*N=5*	*N=6*	*N=9*	*N=6*	*N=9*	*N=6*
Sense of control	2.6	3.83	2.0	3.67	3.86	**4.67**	3.2	**4.0**	3.45	**4.17**	3.44	**4.33**
x̄	3.215		2.835		**4.265**		3.6		3.81		3.885	
Trust in human-automation cooperation	4.1	3.83	4.25	3.5	**4.71**	4.5	4.2	3.33	4.44	4.0	4.33	**4.33**
x̄	3.965		3.875		**4.605**		3.765		4.22		4.33	
Sense of freedom	4.2	3.0	4.0	3.67	**4.71**	4.33	4.2	3.5	4.33	4.0	4.22	4.17
x̄	3.6		3.835		**4.52**		3.85		4.165		4.195	
Ownership of the process	3.8	**4.17**	4.25	**4.0**	4.0	3.17	3.8	3.17	4.2	3.83	4.22	4.17
x̄	3.985		4.125		3.585		3.485		4.015		**4.195**	
Relatedness to the work community	4.2	3.17	4.0	3.33	4.14	3.83	3.8	3.17	4.1	4.0	4.22	3.67
x̄	3.685		3.665		3.985		3.485		**4.05**		3.945	
Meaningfulness of the work	2.9	3.0	4.13	3.33	4.43	4.0	3.8	2.83	**4.56**	3.83	**4.44**	**4.33**
x̄	2.95		3.73		4.215		3.315		4.195		**4.385**	
Success and achievement	3.7	3.83	**4.38**	3.83	4.43	3.83	**4.6**	3.5	4.44	3.67	**4.44**	4.0
x̄	3.765		4.105		4.13		4.05		4.055		**4.22**	
Peace of mind	**4.3**	3.83	**4.38**	**4.0**	**4.71**	4.0	**4.6**	3.5	**4.56**	**4.17**	**4.44**	**4.33**
x̄	4.065		4.19		4.355		4.05		4.365		**4.385**	

I. Assessment of the UX Goals

After seeing each of the SFP scenes, the Web questionnaire and interview participants were requested to fill in a UX goal evaluation questionnaire. Table 1 presents the mean results of the questionnaires, which were similar in both user groups. As the Web user group could choose which scenes to watch (or not watch them all), N varies between scenes. The table demonstrates how the most interesting finding in the UX goal evaluations was with the last UX goal "Peace of mind". In the SFP creation phase, "Peace of mind" was nominated to be the higher level UX goal, but in the evaluations it was treated as one of the eight experiences. However, as Table 1 shows, the participants unanimously scored "Peace of mind" highest in all video scenes, which demonstrate that the participants identified this goal in all of the scenes. The Table also reveals that sequences 3, "Preparation for production change", and 6, "Shift change", were the most successful scenes, as they received the highest scores with 3–4 UX goals.

J. Overall Experience

Before the participants of the Web survey and interviews were introduced to the SFP, they were asked to express, in their own words, their expectations regarding the future control room environment. By answering the question: "How would you describe the overall experience of the future control room?" the participants spontaneously described: *sense of control, skillfulness, happiness, confidence, motivation, enthusiasm, interactivity, situational awareness, easiness, flow, peacefulness, effortlessness, high visual quality, high intelligence and advanced automation*.

After seeing the SFP, the participants were asked to choose the experience that best described their overall experience relating to the future concept; Table 2 presents the results. In the open-ended questions the participants confirmed that the future concept presented in the SFP was well received overall. According to the participants, the SFP was, for the most part, believable and, at least, certainly desirable. The technological concepts were seen to be attractive, as was the visual appearance. The selected interaction methods were stated to be inclusive, as they covered new methods from identification, location, proactive process control and quantified self-data that supported the control room work with innovative means. According to the participants, the level of automation and communication was described convincingly: the machine was left to do what it is

TABLE II. OVERALL EXPERIENCE.

Overall experience	**Web survey**	**Interviews**
Wow	8	-
Very good	4	2
Pleasant	22	4
Conventional	2	-
Unpleasant	2	-
Very bad	1	-

good at: retrieve information and analyze it in order to support human decision-making. Some criticized that the presented future technological advances would not be accomplished by 2025, rather by 2035.

Wearable electronics and head-mounted displays were seen to be the key interaction technologies in future process control work although, according to the participants, these were not described appropriately in the video concepts. Overall, the illustrated concepts were seen to be useful, especially for learning and simulation purposes.

V. Conclusion

The aim of the presented case study was to discover opportunities for new interaction methods and smart automation in future process control work. For achieving this goal, the paper presented a video-illustrated science fiction prototype entitled "Remote operator's day in a future control center in 2025", which included eight nominated UX goals. The SFP offered the participating process control workers a platform to share their experiences and expectations related to potential future work environments, and to identify the benefits of the presented SFP, elaborate on its concepts, and suggest new ideas. By evaluating the video-illustrated SFP, it was also possible to gain an understanding of how the nominated UX goals were received by expert process control workers. It is expected that this line of work may also be applicable to other similar industrial expert work environments.

In this paper it was demonstrated how the reflection part of the SFP process may be employed for experience design investigations and for validating UX goals. It was highlighted in the participants' responses that although the intelligence of the control system increases with new technological advances, it is important that humans make the final decisions. With respect to the technologies to be supported in future process control work, the participants highlighted increasing mobility, wearable electronics and AR glasses. In discussions with experts, the following potential benefits of the new technologies were revealed:

- Speech commands can be used for navigation, opening appropriate views and monitoring.
- Gesture control with wide screen displays is advantageous for training and simulation.
- Real-time access control and location information can improve work safety.
- Game-like experiences may be expected to have a role in motivating future "digital native" operators.

The video-illustrated SFP stimulated a lot of discussion and also helped in provoking new scenarios and ideas. In addition to the presented results, the industrial partner found the video-illustrated SFP to be useful for demonstration and discussion purposes between different stakeholders within the organization. In general, sharing the SFP within the organization is expected to help in committing the company to UX goals and keeping the user's point of view in mind when shifting design and development towards future factories of Industry 4.0. According to the partner company representative: *"Seeing the video-illustrated concept and feeling the tangible prototype facilitated a personal experience of the future potential of new technologies. Videos for demonstrating purposes develop common understanding about the user experience of our future products"*. A lesson learned from the case study was that the user experience driven science fiction prototype offered a powerful tool for illustrating and sharing the future-oriented technology vision.

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References

[1] W. MacDougall, "Industrie 4.0: Smart manufacturing for the future", Germany Trade & Invest, 2014.

[2] B. D. Johnson, "Science fiction prototyping: designing the future with science fiction", Morgan and Claypool Publishers, 2011.

[3] E. Kaasinen, V. Roto, J. Hakulinen, J.P Jokinen, H. Karvonen et al., "Defining user experience goals to guide the design of industrial systems", Behaviour & Information Technology 3001, May: pp. 976-991, 2015

[4] H. Karvonen, I. Aaltonen, M. Wahlström, L. Salo, P.Savioja, and L. Norros, "Hidden roles of the train driver: A challenge for metro automation", Interacting with Computers, 23, 4, 2011.

[5] J. Forlizzi and K. Battarbee, "Understanding experience in interactive systems", in: Proceedings of designing interactive systems DIS, ACM (2005), 261–268.

[6] T. Kymäläinen, P. Perälä, J. Hakulinen, T. Heimonen, J. James, and J. Perä, "Evaluating a future remote control environment with an experience-driven science fiction prototype", 2015 International Conference on Intelligent Environments: pp. 81–88, 2015.

[7] T. Kymäläinen, "Science fiction prototypes as design outcome of research – reflecting ecological research approach and experience design for the Internet of Things", Aalto University, Aalto ARTS Books, 2015.

[8] S. Egerton, M. Davies, B. D. Johnson, and V. Callaghan, "Jimmy: searching for free-will (a competition)", Workshop Proceedings of the 7th International Conference on Intelligent Environments, IOS Press, pp. 128–141, 2011.

[9] T. Birtchnell and J. Urry, "3D, SF and the future", Futures, vol. 50, pp. 25–34, 2013.

[10] S. Ylirisku and J. Buur, "Designing with video, focusing the user-centred design process", Springer Science & Business Media, 2007.

[11] M. Kuniavsky, "Observing the User Experience, a practitioner's guide to user research", Morgan Kaufmann, 2003, pp. 419–437.