Comparing prospective methods to identify latent needs

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ABSTRACT

The digital twin is one of the key technologies of Industry 4.0, thanks to the range of possibilities offered to manufacturers. Given its ability to make decisions and act on its environment, Human-Autonomy Teaming (HAT) can be a key framework for thinking about cooperation between the human agent and the digital twin. In order to deploy an efficient HAT, and given the emerging character of the digital twin, the future needs of human agents in terms of cooperation must be identified. The focus here is on latent needs, characterized by their nature unproved or undreamed by the human agent. We propose to investigate the contribution of the HAT framework to the expression of these latent needs. Through the KHO-KHC model, the objective of the paper is to provide a method from prospective ergonomics to identify latent needs of human agent in terms of cooperation with the digital twin. This proposal is applied to the maintenance planning activity.

CCS CONCEPTS

• **Human-centered computing, Collaborative and social computing theory, concepts and paradigms, Computer supported cooperative work**;

KEYWORDS

Human-Autonomy Teaming, Prospective ergonomics, Digital twin

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1 INTRODUCTION

Technological advances enable autonomous systems to achieve the performance and flexibility required by Industry 4.0 [1]. An autonomous agent can be a digital or cyber-physical entity with its own full or partial self-governance, decision-making, adaptation, and communication capabilities [2]. Designers of autonomous agent focus more on the taskwork and less on the teamwork, the process by which team members cooperate to achieve team goals. However, an autonomous agent must have the ability to cooperate with a human agent [3], for more efficiency in reaching common goals. The Human-Autonomy Teaming (HAT) paradigm has emerged to address these hybrid teams and to think about their cooperation mechanisms [4]. HAT can be defined as a socio-technical system in which at least one human and one autonomous agent interact interdependently over time to accomplish a common task or goal [5]. Although autonomous agent are the subject of debate, they also have the potential to enhance the activity of the human agent [6]. This proposal focuses on this aspect.

In the context of Industry 4.0, these hybrid teams can be formed with the digital twin. The digital twin is one of the pillars of Industry 4.0 thanks to the range of possibilities it offers to manufacturers. The many definitions vary around a common notion: a dynamic, bilateral link between a physical object and a virtual entity that represents it through a data flow [7]. One of the most widespread applications of the digital twin is predictive maintenance. For instance, the digital twin applied to predictive maintenance provides optimization of decision-making concerning the planning of maintenance interventions. The digital twin's ability to make decisions and act on its physical environment makes it necessary to think of the digital twin in terms of HAT. Indeed, new predictive maintenance systems such as those supported by the digital twin must consider the place of human agents [8]. However, the digital twin is an emerging technology with few actual deployments. As a result, the expression of future needs can remain challenging. Applied to the planning activity, the objective of the paper is to provide a method from prospective ergonomics to identify latent needs of human agent. This method aims to provide recommendations to designers for an efficient HAT.

2 RELATED WORK

2.1 KHO-KHC Model

The KHO-KHC appears to be relevant for thinking about HAT, due to its twofold approach. Pacaux-Lemoine et al. [3] defines two abilities that agents must have to cooperate. Firstly, the internal and external "Know-how-to-Operate" (KHO), which refers to the cooperating agent's specific knowledge of how to solve a problem related to the activity conducted. Therefore, KHO is related to the taskwork. Applied to the maintenance activity, the KHO may refer to the digital twin's ability to plan an intervention on equipment. Related to teamwork, the "Know-how-to-cooperate" (KHC) refers to knowing how to cooperate with its partner. Compared with the maintenance schedule, the KHC may refer to the digital twin's

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Table 1: KHO-KHC model [3]

KNOW-HOW-TO-OPERATE (KHO): Specific knowledge to each cooperating agent
Internal: skills of each cooperating agent (i.e., expertise, experience)
External: obtain information from the environment and acting of the process
KNOW-HOW-TO-COOPERATE (KHC): Know how to cooperate with your partner
Internal: build a model and deduce your partner's intentions, analyze tasks, and identify cooperative organization, produce a common plan
External: understand and provide information to your partner

ability to propose a date adjustment for the maintenance operation. Table 1 shows the different dimensions of KHO et KHC abilities.

These two attributes are necessary for each agent to cooperate efficiently, and then, address challenges provided by Industry 4.0. To implement efficient HAT, prospective ergonomics could provide a framework to envision this cooperation.

2.2 What is Prospective Ergonomics?

Prospective ergonomics completes the intervention modalities of corrective and design ergonomics, by aiming to anticipate future needs [9]. In this perspective, prospective ergonomics proposes methods such as the needs anticipation interview, and specific profiles such as experts in the field studied, recognized for their ability to express future needs [10].

Prospective ergonomics considers different levels of need granularity, including functional needs (i.e., objectives to be achieved by the digital twin) and hedonic needs (i.e., quality of experience for the human agent). However, these needs can be hard to identify for human agents. Robertson [11] proposed the following typology:

-Conscious needs: proven needs clearly expressed by the human agent. This type of need focuses on the human agent, without evoking any technical or technological means of achieving it.

-Unconscious needs: proven needs that have not been explicitly evoked by the human agent. Technical or technological means are evoked, without citing a specific human agent need.

-Latent needs: unproven needs that the human agent has not yet identified. Understanding the potential offered by technology is essential to access latent needs. Thus, expressing this type of need requires a framework for simulating how the technology could work [12].

Identifying latent needs is a major challenge for the development of emerging technologies such as the digital twin [13] [14]. According to our state of the art, research in prospective ergonomics has not addressed the identification of latent needs related to cooperation. However, future uses of the digital twin should support HAT for effective cooperation.

2.3 Questions

Studies in prospective ergonomics show that the complexity of emerging technologies, such as digital twin, makes it difficult to express future needs [12]. Therefore, access to latent needs requires a framework for their expression, enabling participants to have a pre-experience related to the future activity. In addition, prospective ergonomics methods have not yet considered the HAT theoretical framework for thinking about future cooperation between the human agent and the digital twin. We propose to investigate the contribution of the HAT framework to the expression of latent needs. Through the KHO-KHC model, the objective of the paper is to provide a method from prospective ergonomics to identify the needs of human agent in terms of cooperation with the digital twin. We hypothesized that the framework proposed by the KHO-KHC model will enable participants to live a pre-experience in terms of cooperation with the digital twin, thus favoring the expression of latent needs.

3 METHODOLOGY FOR DESIGNING COOPERATION BETWEEN DIGITAL TWINS AND HUMANS

3.1 Needs anticipation interview

The needs anticipation interview is based on tools and methods developed by prospective ergonomics [10]. This semi-directive interview consists in identifying needs by facilitating the representation of the human agent's future. By using the future needs anticipation interview, we aimed to compare two modalities: an opened-ideation modality, and a guided-ideation modality based on the KHO-KHC model. We also aimed to evaluate the guided-ideation modality according to the profile of the participants, i.e., experts and novices in maintenance planning activity. Figure 1 summarizes the proposed methodology.

The common phases of the three studies are as follows:

-Priming: the objective of this phase is to evoke the maintenance planning activity generally.

-Experiment: the aim was to discuss the daily tasks involved in maintenance planning activity. Based on an activity analysis and validated with an expert, five planning-related tasks were presented to the participants (e.g. meeting deadlines for interventions, optimizing the execution of several interventions). Participants were asked to describe the task in general terms, and then to describe one positive and one negative experience for each task.

3.2 Modalities of the three studies

Study 1: Opened-ideation modality with experts

The first study was applied to the maintenance planning activity of a major French railway company, a SPIE Industrie client. Nine planning supervisors at SPIE Industrie have been recruited for this study. After the priming and experience phase, the interview was structured as follows [10]:

-Ideation: the aim was to project the participant into the future. Referring to the previously mentioned experiences, the participants

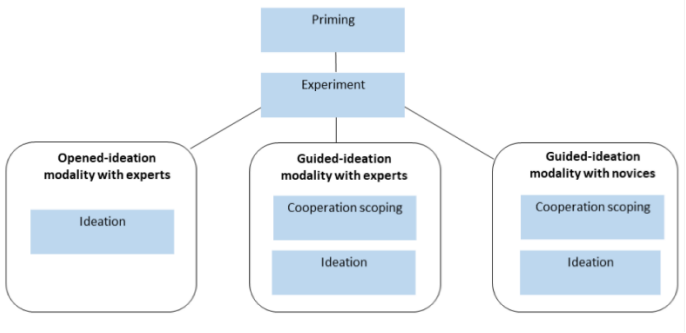

Figure 1: Methodology

were asked how positive experiences are to be maintained and how negative experiences are to be transformed. To do so, participants were asked to imagine being in charge of planning activity in 2050. They were told that in this future, a digital twin would help them in their daily planning activities, and that they could express their ideas without censoring themselves. Participants were also allowed to express ideas that were not related to the five tasks.

Study 2: Guided-ideation modality with experts

The second study was still applied to the maintenance planning activity of a major French railway company. Six new planning supervisors at SPIE Industrie have been recruited for this study. After the priming and experience phase, the interview was structured as follows:

-Cooperation scoping: The aim was to present how cooperation with a digital twin might unfold in the future. To do so, participants were first asked to imagine being in charge of planning activity in 2050. They were told that in this future, a digital twin would help them in their day-to-day planning activities. The KHO-KHC model was then presented to the participants with the help of a visual support.

-Ideation: The aim was to keep the participants in the future, so that they could express needs related to cooperation with the digital twin. KHO questions were related to the digital twin's ability to gather information, analyze problems, make decisions and implement them. KHC questions will be related to the digital twin's ability to understand the skills and intentions of the human agent, and to communicate information to him. The presentation of the KHO-KHC model remains available to the participant during the ideation phase.

Study 3: Guided-ideation with novice

Study 3 will be applied to the production planning activity. Ten industrial engineering master students will take part in the study. The interview will be structured as study 2.

4 DATA ANALYSIS METHOD

4.1 Identify conscious, unconscious and latent needs

The expressed needs are evaluated on a score regarding feasibility, relevance [15] and explicit criteria [16]. As the criteria are generic, we have operationalized them to meet the objectives of the study:

-Feasibility: the expressed need constitutes an aid provided by the digital twin and can be easily implemented within the planning activity at SPIE Industrie in the future.

-Relevance: the expressed need constitutes an aid provided by the digital twin to solve a problem related to the maintenance planning activity. The expressed need will be effective in solving this problem in the future.

-Explicit: the expressed need which constitutes an aid provided by the digital twin is clearly expressed and specifically articulated.

Firstly, the researchers will establish a list of needs based on the interviews conducted. This list will be presented to three raters to determine a latency score. The three raters have expertise in innovation and digitalization, planning activity and digital twin respectively. The needs will be evaluated according to the three criterions, on a Lickert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Acceptable levels of agreement between raters will be determined using a Cohen's Kappa. According to the average of the three criterions, a latent need will correspond to a higher score than a conscious or unconscious need. Statistical tests will enable to compare which method was more efficient in expressing latent needs. In addition, it will be possible to determine with which profile the guided-ideation modality is most effective.

4.2 Expected results

Given the framework proposed by the KHO-KHC model, we hypothesize that more needs will be expressed with the guided-ideation modality than with the open-ideation modality. More latent needs will be expressed with the guided-ideation modality than with the opened-ideation modality.

Regarding expertise profiles, we hypothesize that novices will express as many latent needs as experts. The pre-experience offered by the KHO-KHC model would overcome the non-expertise of novices.

5 CONCLUSION

The aim of the proposal was to provide a prospective method based on the KHO-KHC model, allowing human agents to think about their future cooperation with the digital twin. We sought to compare two methods to assess which one allowed the expression of latent needs. Besides, we sought to compare with which profile

the proposed method would be most effective. Based on needs anticipation interview [10] the first study was related to the opened-ideation modality with experts. The second study was related to the KHO-KHC model, providing experts a framework for thinking about future cooperation with the digital twin. Finally, we aimed to reproduce the guided ideation with novice participants in the third study. Identifying latent needs is a key issue for the deployment of new technologies such as the digital twin. Such a method will allow manufacturers to design a digital twin adapted to future needs and deploy an efficient HAT. This research is part of an Industry 4.0 project within a company specializing in maintenance services. In this context, the two first studies were conducted on future users of the digital twin at SPIE Industry. In order to generalize future results, the methodology should be applied to a larger number of participants. Finally, we have chosen the needs anticipation interview to apply the KHO-KHC model. An interesting perspective would be to apply the KHO-KHC model to another future projection methods, such as persona or simulation.

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