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Challenges for the Operator 3.0 Addressed Through the Enabling Technologies of the Operator 4.0

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Abstract. Just as human operators are important production enablers in the factories of today, they are expected to stay key enablers also in future manufacturing. In today's factories, operators often meet challenges related to poor information and communication design, which affects their possibilities to perform with higher efficiency levels. Therefore, they need to be provided with better cognitive support tools that are relevant to the challenges to be met. To ensure efficient and effective operator work in the factories of the future, operator support needs to be adequate for the new tasks arising from the evolving operators' roles and work. Within this paper, the results of current operators' work and challenges, based on six case studies, are combined with an outlook of the future of work of operators, based on the Operator 4.0 vision. The challenges categorized in this paper can be used to identify opportunities for improvement in the operators' cognitive support in present factories as well as for researchers and developers of Operator 3.0 support solutions.

Keywords: Cognitive Ergonomics, Operator Support, Operator 4.0, Tasks.

1 Introduction

In recent years there has been a massive and broad technological development in society, with opportunities as computing, analysis, information and communication technologies (ICT) as a few examples [1]. The anticipated benefits of applying advanced technology in production companies have led to initiatives such as *Industry 4.0* and *Smart Manufacturing* among others [2], and the appearance of the *Fourth Industrial Revolution* [3].

Even though the operational and informational technologies have evolved, the challenges of the operator of today remain. In current factories, operators face difficulties relating to information and communication, these challenges affect their possibilities to perform with higher efficiency levels. Therefore, operators need to be provided with better cognitive support tools, relevant for their tasks and challenges to be met. However, what should this type of cognitive operator assistance support?

Technology focus and usage is often the starting point for discussing “operator support”, which is not surprising considering the technology drive of *Industry 4.0*. It could lead to shortages of a holistic perspective on the operators’ tasks. Tarrar [4] attempted to identify and describe the challenges met by operators regarding information and communication processes from a holistic perspective, studying issues and improvement potential in the operators’ work. This paper builds upon these challenges that are further developed. To ensure efficient and effective operators’ work in the factories of the future as well as in the present factories, operators’ support needs to be adequate for the new tasks arising from the evolving operators’ roles and work.

This paper aims to analyse and connect the challenges from Tarrar [4] with the recent development of *Industry 4.0*, and specifically the *Operator 4.0 vision*. Furthermore, the paper will discuss potential benefits relating to the enabling technology scenarios of the Operator 4.0 in combination with the aforementioned challenges.

2 Challenges for the Operator 3.0

The challenges, first published in Tarrar [4], were based on six case studies in four large Swedish companies from the medical equipment, tooling, component, and automotive industries. The companies were considering improvements in information and communication support for their operators. The operators performed: (I) Machine/process supervision and maintenance, disturbance handling, production improvements, planning of work, and to some extent assembly; or (II) Assembly of special features, pre-assembly and planning of work all requiring high product and production knowledge; or (III) Machine/process supervision with testing, with either some assembly or maintenance. The operators in four of the cases (Tasks I & II) had broader responsibilities and conducted more tasks themselves than the common operators in the industry [5]. The connection between the companies, cases and operator tasks are displayed in Table 1.

Table 1. Industrial Cases Serving as the Foundation for Identifying the Operator 3.0 Challenges

Company	Medical Equipment	Medical Equipment	Tooling	Automotive	Component	Component
Operator Tasks	I	III	I	II	III	I
Challenges	3,4,5	2,3,4,7	1,2,3,5,7	1,3,4,6,9	2,3,5,6,9	1,3,4,8

In each case, data was gathered through: semi-structured interviews held with managers and operators; observations; and surveys. Difficulties and opportunities were identified from the gathered data, through content analysis and grounded theory these were combined into ten general operator challenges relating to the information and communication requirements in the operators’ work.

Despite the variability of operators’ tasks, there could be challenges not included here. The identified challenges can exist in different combinations within companies and departments. From the original challenges, the first three were combined into two and the following were kept. Totally nine challenges are presented below:

1. *Know what task to perform* – For common tasks, knowing what task to perform is often done by memory, i.e. an assembly worker knowing what part to assemble to a workpiece. However, infrequent tasks are easily forgotten and this coupled with poor quality or availability of instructions, may lead to work performance issues.
2. *Know how to perform a task* – The knowledge of how to perform a particular task is often acquired during training. However, updates to the task, disturbances, or contextual changes might require new tasks or ways to perform a task. The memory of how to perform a specific task is also highly affected by the level of variation in work tasks, a high product variation entails a higher cognitive demand as more bits of information needs to be remembered. Furthermore, the challenge can occur for complex and difficult analysis and problem-solving tasks, were experience is acquired slowly. It can also occur in very long tasks or task times. A task which recurs rarely is naturally more difficult to remember.
3. *Knowing and conveying what tasks have been carried out* – Keeping track of task status and the status of the overall objectives is as much a matter of securing relevant information to perform a job as well as a psychological aspect that influences mental workload and operator wellbeing [6]. It could be challenging when several operators share the responsibility; or when assembly times are long. To a large extent, this is aided by properly designed information interfaces, especially made easier through digitalized information systems. And further simplified where connections between the information system and the tools used can help the user keep track of the work status. The challenge also includes communicating task status to others or even to the operator himself at another point in time. David Kirsh discussed the term entry points [7] to describe an “invitation to do something” (p.311). Other works [8] have identified similar aspects of leaving cues in the environment for oneself where a worker when leaving their work station to take a break or help a colleague, would leave their work gloves or a particular tool on the workpiece to indicate task status once they returned. Essentially creating an entry point for themselves to resume work.
4. *Passing on information and communicating statuses* – such as audio or visual impressions of the product, process, or machine, to others not present. Also, information to oneself in the future to remember some characteristics of a situation. An example could be an operator experiencing a possible miss-sound and wondering if there is a problem or if it is okay, the sound is hard to capture in text and not always possible to transmit through tools and systems available.
5. *Finding and understanding products, machines, or process statuses and information* – is relevant in situations with e.g. alarms or breakdowns. Difficulties are typically caused by difficult interfaces or codes (e.g. error messages/codes, given by the product or a system interface) that are unintuitive and hard to understand; or when process information and statuses are hard to find. An example is to discover what caused the machine to stop when there are very many error codes following the stop.
6. *Handling different computer systems* – caused by poor usability, overlapping systems or systems with low perceived benefit of using. The issues could result in operators asking someone else to use the system(s) and perform the task, or complete circumvention of the system, for example, calling maintenance personnel instead of

reporting in the system. Systems smartly designed with perceived usefulness largely addresses the issues.

7. *Performing task(s) and supervising machines, or processes at the same time* – when reviewing automatic process steps, it may be necessary to carry out other tasks such as tending to other processes, machines or quality controls. This implies that visual or audible contact with the machine or process interface may be lost, which could cause stress or late responses to deviations.
8. *Transmit health and safety information in case of an emergency* – in case of personal health issues or risks in the environment of the operator. For example, while working in locations difficult to see for others. Or in case something happened, send information so the rescuer can deal with the specific threat.
9. *Locating products, tools, and materials* – when these are not at the desired place, or when one does not know where to go. For example maintenance personnel looking for the exact location of a machine or a specific small detail in a large process.

3 The Operator 4.0 and the Future of Work

Perfect forecasts of future manufacturing and operators' work are impossible to make. However, researchers have suggested possible paths of development for the future of work of operators, in this paper the focus is on the Operator 4.0. The *Operator 4.0* was introduced by Romero, et al. [9] as a way to highlight the role of the operator as a smart and skilled worker enhanced through technology within the Industry 4.0 context. Furthermore, it has been predicted that the future of work of operators will include increased problem-solving and analysis [10-12], indicating a need for further information to facilitate decisions [13]. Parts of these decisions could be made through the information systems, however, data availability and quality need to be improved [9, 10, 13].

3.1 The Skills Forecast for the Operator4.0

The vision of the *Operator 4.0* is to create trusting and interaction-based relationships between humans and machines and to empower the “smart operators” with new skills and gadgets to fully capitalize on the opportunities being created by the enabling technologies of *Industry 4.0* [9]. Within the enabling technologies [14], seven out of nine can be connected to information and communication processes considering the operator, i.e. IIoT, Big Data, Real-time Optimisation, Cloud Computing, Cyber-Physical Systems, Machine Learning, Augmented Reality (or xR-Technologies). These technologies have a machine and technology focus but to create wellness for the operator a strategy based on the *Operator 4.0 vision* is needed [15]. Within the taxonomy of *Operator 4.0*, skills needed from both the enabling technologies and wellness of the operator are included, however, the collaborative and super-strength operators are not applicable here and are therefore omitted. Different types of Operators 4.0 are discussed:

- *Augmented and Virtual Operator* – uses xR technologies as assisting means in training, maintenance, and complex tasks [16-18].
- *Healthy Operator* – uses smart wearable solutions (i.e. wearable trackers for health-related metrics) including data analytics capabilities together with advanced human-

machine and human-automation interfacing/interaction technologies for his/her physical and physiological wellbeing management [19].

- *Smarter Operator* – uses an intelligent personal assistant, or other types of softbots, which have been developed to help an operator in interfacing with machines, computers, databases, and other information systems as well as managing time commitments and performing tasks or services in a human-like interaction [20, 21].
- *Social Operator* – uses social networking services, enabled by real-time mobile communication capabilities, to empower his/her colleague operators by contributing with his/her expertise across the production line and the whole shop-floor. *Social Operators* can accelerate ideas generation for product and processes innovation and can facilitate problems-solving by bringing together the right people with the right information within the enterprise [22].
- *Analytical Operator* – uses (big) data analytics techniques to leverage real-time information for driving the right response to prevent mistakes, quickly identify problems, and call for the right decisions to improve operational efficiency [9].

4 Addressing Challenges for the Operator 3.0 through Enabling Technology Scenarios from the Operator 4.0

Many of the challenges of the *Operator 3.0* can be addressed through the technological enablers of the *Operator 4.0*. In Table 1, the challenges and technologies are mapped together.

Table 2. Challenges of the Operator 3.0 Connected to the Skills of the Operator 4.0

Challenges/Skills	xR Operator	Healthy Operator	Smart Operator	Social Operator	Analytic Operator
1. Know what task to perform.	X		X		X
2. Know how to perform a task.	X			X	
3. Know and convey what tasks have been carried out.			X	X	
4. Pass on information and communicate statuses.			X	X	X
5. Find and understand products, machines, or process statuses and information.			X		X
6. Handle different computer systems.			X		X
7. Perform task(s) and supervise machines or processes at the same time.	X		X		X
8. Transmit health and safety information in case of an emergency.		X			
9. Locate products, tools, and materials.	X		X		X

The Xs in Table 1 indicate the *Operator 3.0* challenges that can be supported by the *Operator 4.0* vision, and will be discussed in the following bullet-points:

- *Know what task to perform* (challenge) – can be addressed by (i) the *xR Operator*, which uses xR technologies as visual triggers that quickly prompt the operator’s memory on what to do; (ii) the *Smarter Operator* and his/her intelligent personal assistant (e.g. a softbot) that would enable hints to ensure the operator is aware of product/process/machine characteristics affecting a task; and (iii) the *Analytical Operator*, who leverages the data available on the task at hand (e.g. a report) combined with the operator’s previous experience/performance to support “remembrance/remembering/acknowledging” what to do and draw attention to differences.
- *Know how to perform a task* (challenge) – can be addressed by (i) the *xR Operator* enhancing his/her understanding of the task at hand (i.e. the procedure) through a digital-assistance system providing visual instructions overlaid in real-time in the operator’s field of view; and (ii) the *Social Operator* that enables real-time interactions with other smart, connected operators and things (e.g. machines, computers, databases, and other information systems) using mobile and social collaborative methods to retrieve advice and know-how on how to perform a task.
- *Knowing and conveying what tasks have been carried out* (challenge) – can be addressed by (i) the *Smarter Operator* through alerts provided by his/her intelligent personal assistant on tasks not performed yet according to a working plan, and (ii) the *Social Operator*, when the reminders could come from his/her “connected” supervisor or a smart, connected machine “calling” for attention (e.g. a digital Andon system) so the task gets performed.
- *Passing on information and communicating statuses* (challenge) – can be addressed by the (i) the *Smarter Operator*, which shares information and sends updates on statuses with the help of his/her intelligent personal assistant that sorts, filters, and delivers the information collected and statuses of machines and processes validated to the right persons and/or systems to get a task performed; (ii) the *Social Operator*, who uses mobile devices and enterprise social networks to share the right information, at the right time, to the right person) and/or systems to get a task performed; and (iii) the *Analytical Operator* that uses data analytic techniques to automatically transform data into information to support and accelerate a task performance.
- *Finding and understanding products, machines, or process statuses and information* (challenge) – addressed by (i) the *Smarter Operator*, who receives statuses and relevant information previously found, sorted, and filtered by his/her intelligent personal assistant so he/she can react on time to the task at hand; (ii) the *Social Operator*, which is real-time connected with other smart, connected operators and things that he/she can reach out to consult and query to support and accelerate a task performance; and (iii) the *Analytical Operator*, which uses data analytic techniques to obtain insights from (big) datasets that can help to improve a task performance.
- *Handling different computer systems* (challenge) – addressed by (i) the *Smarter Operator*, which receives support from his/her intelligent personal assistant to oversee all computer systems and receive an alert when human intervention is needed; and (ii) *Analytical Operator*, who uses artificial intelligence to automate certain tasks to reduce the handling effort of different computer systems.

- *Performing task(s) and supervising machines or processes at the same time* (challenge) – addressed by (i) the *xR Operator*, who uses digital assistance systems and digital poka-yokes to prevent mistakes and perform all his/her tasks without errors; (ii) the *Smarter Operator* that counts with an intelligent personal assistant to support the performance of his/her tasks; and (iii) the *Analytical Operator*, which uses real-time data analytics techniques (e.g. computer vision systems) to analyse a task as it is being performed, and receive immediate feedback to quickly identify problems and take the corrective actions on time.
- *Transmit health and safety information in case of emergency* (challenge) – addressed by the *Healthy Operator* who uses smart wearable solutions to track his/her health-related metrics to self-manage his/her physical and cognitive workload, and if this information is shared in an anonymized way could help production planners to foster better industrial hygiene by better planning and controlling the workforce workloads as they perform their tasks.
- *Locating products, tools, and materials* (challenge) – addressed by (i) the *xR Operator* which shows directions (ii) the *Smarter Operator*, who uses the support of his/her intelligent personal assistant to locate smart things, which have a smart tag such as a GPS, so his/her task performance doesn't get delayed due to the search; and (iii) the *Analytical Operator*, which uses data analytic techniques to obtain insights on data related to assets location, condition, availability, etc.

5 Conclusions and Further Work

Several challenges concerning information and communication processes were identified covering current and future work of operators. The industry of today is still facing a lot of challenges when it comes to information and communication technologies, and foremost support for the operators. Even if the technologies are evolving, the organisations, the smart factories, need to evolve at the same pace to get skilled *Operators 4.0*. To know what tasks and how to perform them together with knowing what steps of the tasks have been carried out, are the most general challenges for the operators with the others being more specific to the operator work/task at hand. The challenges identified in this paper could be used to identify the needs to support the operators at the factories of the future.

Further work is needed to address the severity of the information and communication challenges in correlation to different types of operators' tasks, operator experience and production types. Moreover, the tasks of operators in the factories of the future need more attention to understand/predict possible challenges for future operators.

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