Collaborative Robots Entering the Factory Floor: Why We Need HR

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Abstract

Using the latest industrial robot technology, the collaborative robot (cobot), industrial manufacturers work towards high-mix low-volume production systems that could satisfy a diversifying customer demand. As the utilization of the cobot's potential depends on the dynamic interaction with operators, one would expect HR professionals to play a central role in this implementation process. However, cobot-related literature is unanimous: HR is not involved.

This is in line with the results of our study in 2019 on seventeen cobot experiments in Dutch industrial manufacturing companies. To explore what human cobot collaboration emerges when engineers and line managers take the lead in their design, we revisited the data from our previous interview study (N=53). HR was absent in all implementations.

We found that line managers and engineers prepared operators for rigid human-cobot collaborations that were aimed at getting the cobot to work, enhancing production efficiency and handling a few batches of mass-produced goods (low-mix, high-volume). Furthermore, the collaborations all showed signs of being difficult to sustain over time and posed a direct threat to operators' well-being.

To protect operators' future of work and build towards interdependent human-cobot collaboration suitable for high-mix low-volume production, we propose an approach in which operators themselves, and HR too, are much more involved in the cobot implementation process. Operators should be allowed and supported to design, program, operate, and repair as much of their human-cobot workstations themselves as possible. To support this, HR has to familiarize itself with the cobot technology, secure operators' decision latitude, facilitate the required support, and become the work design expert that helps operators co-design sustainable cobot applications that optimally utilize the strengths of both man and machine.

Topics: Human-Cobot Collaboration, Future of Work, Technology Implementation, Smart Industry, HR

Towards Flexible Production Systems with Cobots

Industrial manufacturers are confronted with an increasing number of customers demanding small batches of high-quality and tailor-made products at the price of mass-produced goods (Zhang & Tseng, 2009). To satisfy these demands, their production system must be capable of handling the requested variety at low volumes efficiently (Becker, Borst, & Van der Veen, 2015) . Industrial manufacturers experiment with collaborative robots as a possible solution to ultimately achieve efficient high-mix, low-volume production.

Different from other industrial robots, cobots are small-sized, easy-to-program robot arms that can directly interact with operators (Villani, Pini, Leali, & Secchi, 2018). Cobots are known for their high and tireless accuracy, generating opportunities to increase productivity and product quality (Wang, Kemény, Váncza, & Wang, 2017). Given their multi-purpose capabilities and ease-of-programming, they can be used in production environments where a wide variety of products are produced. As such, they have the potential to bring industrial manufacturers closer towards high-mix, low-volume production.

However, cobots cannot handle actions, issues, and unanticipated situations they are not programmed for. This is problematic in a dynamic and unpredictable environment (Wang et al., 2017), such as high mix-low volume production, in which handling, programming, parts and lead times for example, change frequently and (preferably) rapidly. When cobots are confronted with many and frequent changes or unpredictable variance, operator-interference is crucial. Operators add the flexibility, adaptability, and decision-making capabilities that cobots lack (Gualtieri, Palomba, Wehrle, & Vidoni, 2020). This means that the effectiveness and resilience of human-cobot collaboration depends on the 'interdependence' between the cobot and the operator. Interdependence occurs "when what one party does depends on what another party does (and vice-versa) over a sustained sequence of actions" (Johnson, 2014, p. 25).

Key Issues when Establishing Interdependent Human-Cobot Collaboration

The quality of the human-cobot interdependence depends on the operator meeting the following three demands. First, the operator must be willing to collaborate with the cobot. Second, the operator must be capable of establishing interdependent human-cobot collaborations. Third, the operator must be capable of sustaining the collaboration.

According to the Unified Theory of Acceptance and Use of Technology (Venkatesh, Morris, Davis, & Davis, 2003), user willingness requires one to believe in the technology's added value, its ease-of-use and its significance to important others. How the technology is used eventually, furthermore depends on the support that was provided to the user (e.g., available assistance), according to this theory.

Second, successful human-cobot collaboration depends on three system properties, according to Johnson (2014): observability, predictability, and directability. In all three, operators play a crucial role. Observability, from a human perspective, is accurately sensing and interpreting the machine's signals and sending the right signals (observable by the machine) back. Predictability means successful human forecasting of the machine's behavior and behaving predictably towards the cobot. Directability means having the right control to steer the behavior of the cobot and being controllable by the machine to a certain extend. Thus, before operators can establish an interdependence human-cobot collaboration they should have the right capacities that meet the observability, predictability, and directability requirements.

Third, modern socio-technical systems thinking (De Sitter, Den Hertog, & Dankbaar, 1997) prescribes that work with complex technology is only sustainable when designed properly. Technical and social systems should be jointly optimized and human labor should meet specific and well known requirements. These so-called work design characteristics (Hackman & Oldham, 1976; Humphrey, Nahrgang, & Morgeson, 2007), prescribe the motivational (e.g., autonomy, task variety), social (e.g., interdependence, feedback from others), and work context characteristics (e.g., ergonomics, physical demands) an individual worker should perceive to stay productive, healthy, and motivated at work. Whether the operator experiences these characteristics when working together with a cobot depends on the task allocation between the cobot and himself.

A suboptimal task allocation between operator and cobot, one where the cobot executes too many or too significant tasks, results not only in unsustainable work design, it also provokes operator-out-of-the-loop problems (Kaber & Endsley, 1997). These classic automation problems occur in case a technology plays too prominent a role in the collaboration and detaches operators from the primary process (Gouraud, Delorme, & Berberian, 2017). As a result, the operators' situation awareness decreases (Endsley, Sollenberger, & Stein, 2000) and they cannot monitor the system effectively (Onnasch, Wickens, Manzey, 2014)(Onnasch, Wickens, Li, & Manzey, 2014). Operator-out-of-the-loop issues decrease performance and could lead to dangerous and even lethal incidents as it becomes increasingly difficult for the operators to adequately react to system malfunctions (Manzey, Reichenbach, & Onnasch, 2012).

Modern socio technical systems thinking (De Sitter et al., 1997), recent work design studies (Parker, Morgeson, & Johns, 2017), and the workplace innovation literature (Oeij, Dhondt, Pot, & Totterdill, 2018) all agree that operators should have decision latitude to decide over the organization and execution of their work, to prevent the problems just described. Having the opportunity to design their own human-cobot collaboration, operators can align their task allocation with their work design preferences and have better jobs as a result. However, for operators to design their work properly, they should master the right skill discretion accordingly (Karasek, 1979; Parker, Andrei, & Van den Broecke, 2019) and they should get both support and help from operational management and engineers.

In conclusion, implementing cobots in high mix, low volume production systems has its challenges. One needs interdependent human-cobot collaboration. Designing such systems in a way that works and is humanly sustainable requires not only good engineering, intimate knowledge of production systems and adequate operational management, it needs willing and able operators as well, that participate in designing interdependent collaboration with proper characteristics. Operators need support and help to do so.

An increasing number of Dutch production companies experiment with implementing cobots into their production systems. We previously studied 17 such experiments and reported on our findings (Wolffgramm, Corporaal, & Van Riemsdijk, 2019). Theory suggests that effective and sustainable collaborative human-cobot designs ask for active engagement of operators. Therefore, and using our previous findings, we now want to answer two questions for the design of effective human-cobot collaboration;

1. What is the level of operator participation and support in the design and implementation of these experimental human-cobot collaborations?

2. What is the perceived effect on their work according to operators?

To answer these two central questions, we will address the following sub questions:

1. What kind of experimental collaborations were designed?
2. What decision latitude did operators get?
3. What support did they receive?
4. What were the effects on the work perception of the operators?
5. What is the perceived effect on production?

After presenting our results, we will address the role HR could -and we think should- play in the design and implementation of human-cobot collaborative production systems.

Method

We re-analyzed the data from our previous interview study (N=53) on cobot implementations in Dutch industry (Wolffgramm et al., 2019). This study included engineers, line managers, and operators from seventeen industrial manufacturers and three mechatronics research groups. All interviewees had recent working experience with a cobot and participated in the cobot implementation processes. The cobots under study were implemented in production systems handling both large and small product batches (e.g., plastics, metal parts, small devices and electronics). Using a semi-structured interview protocol, data was collected about the division of tasks between operator and cobot, how cobots were implemented, and what expected outcomes were generated through interdependent human-cobot collaboration. All interviews were recorded, converted into verbatim transcripts, and imported into coding software tool Atlas.TI.

As literature provides a clear conceptual basis and rich operationalization about support (Venkatesh et al., 2006), decision latitude (Karasek, 1979), work design (Humphrey et al., 2007), operator-out-of-the-loop (Kaber & Endsley, 1997) and performance (Beamon, 1999), we used a deductive coding approach to analyze the interview data. Inspired by Fereday and Muir-Cochrane (2006) , the data was coded in three steps. First, the variables' factors (e.g., motivational characteristics) were used to search the data for relevant quotes. Second, the coded quotes were related to one of the factors' underlying items (e.g., task variety). Third, for each item, quotations were compared to determine the state of the variable. Inter-rater reliability (Lincon & Guba, 1985) was established as the data was independently coded by three researchers. Coding structures were compared to agree upon a final coding structure to use.

Results

Starting with the operators' decision authority, the following four divisions of responsibilities between line managers, engineers, and operators provide insight into the opportunities operators had to directly influence their human-cobot collaboration. First, engineers and line managers decided over the task allocation between operators and cobot – operators had an advisory say in the design process. Second, operators had to operate the cobot using pre-programmed programs they were not allowed to alter. These programs were created by engineers. Third, the cobot directed the organization and pace of the operators' work. As operators had to timely supply the cobot with products to handle and processed the products that were handled by the cobot, its speed determined how fast operators had to work to prevent the process from stagnating. Fourth, operators had limited degrees of freedom to repair the cobot in case of a malfunction. Engineers had to be called to the workstation in case cobot-related issues could not be solved by rebooting the cobot.

In terms of support, line managers arranged four facilitating conditions. First, operators attended a demonstration that provided visual insight into the cobot's movements and applications. The demonstrations were hosted by either engineers or cobot suppliers. Second, line managers and engineers provided operators with information about: the definition of a cobot, the rationale behind implementing a cobot, and what the cobot would be used for. Third, engineers hosted a brief workplace training through which operators learnt how to switch-on the cobot, select one of the programs, carefully load and unload products, and reboot the cobot. Fourth, engineers distributed booklets at the workstations prescribing, step-by-step, how to start, operate, and troubleshoot the cobot.

Zooming in operators' work perceptions, we found that operators perceived their work design to be either simplified or complicated by the cobot. In all cases, cobots took over the operators' most simplistic and routine tasks. Whether operators experienced job complexity, task variety and information processing seemed to depend on the (lack of) additional responsibilities that were ascribed them. Operators who experienced a more simplistic work design reported that the cobot took over more tasks than were newly-ascribed to them (e.g., loading and unloading the cobot). The decreased number of tasks made their work less complex and varied as it became increasingly repetitive.

Operators who perceived their work design to be more complex after the introduction of the cobot had to maintain the cobot and run a parallel production process at the same time. These operators considered their work to be more complex and mentally-exhausting as they had to divide their attention between the cobot and other, unrelated and parallel, tasks and had to process more information accordingly. In some cases, operators had to walk back-and-forth between workstations to perform their parallel tasks as well, making work more physically demanding too. Furthermore, these operators tended to experience most operator-out-of-the-loop problems, as they could not always see the cobot from where they were conducting their parallel tasks. Multiple examples were found where operators assumed the cobot was functioning well while, in fact, it came to a hold. Various indications of decreased situation awareness were found as operators lacked the capabilities to fully comprehend the cobot's application and predict its movements.

In terms of perceived performance, the human-cobot collaborations under study were used for the handling of standardized products. Batch sizes varied from 100 to 30,000 items – most collaborations handled thousands of similar products. Most cobots were equipped with one to five prewritten programs, indicating the number of changeovers. And although fully-loaded cobots were able to produce autonomously for around two hours, the human-cobot collaborations under study came with high manufacturing costs as it took engineers significant effort to program the cobots for their autonomous operation. Another problem was that several cobots were collecting dust since the particular products they were programmed for were no longer being ordered. Other examples of cobot downtime were caused by operators who were unsuccessful at timely reloading the cobot, overrelied on the cobot's performance, or awaited engineers to repair the cobot.

Where is HR?

In all our cases there was no role for HR. Multiple line managers and engineers mentioned they were capable of preparing operators for interdependent human-cobot collaboration without HR's help. This is not exceptional. In many cobot implementation plans and case studies HR's role in the cobot implementation process is not mentioned at all (Libert, Cadieux, & Mosconi, 2020). This in contrast to the role played by line managers and the activities executed by engineers (Malik & Bilberg, 2017; Kadir, Broberg, & Souza da Conceição; Broum et al. 2019). That HR is not mentioned in cobot-related literature could be attributed to the over-emphasis on the technical aspect of interdependent human-cobot collaboration. The majority of these publications is primarily concerned with conducting production process analyses, living up to safety regulations, and leveraging the cobots' technical potential (Schou, Andersen, Chrysostomou, Bøgh, & Madsen, 2018; Weckenborg, Kieckhäfer, Müller, Grunewald, & Spengler, 2019; El Makrini et al., 2019). It can also be caused by HR not being connected to these new production techniques, as happened previously in the case of business process redesign (Storey, 1992), or it could be that HR doesn't really see how its knowledge could contribute.

With HR not participating thus far, it is up to line managers and engineers to provide operators with the required decision latitude and support to design interdependent human-cobot collaborations. Based on our findings so far, we suspect that making line managers and engineers fully responsible for handling the HR implications of interdependent human-cobot collaboration poses a serious threat to both the design and its sustainability. First of all, line managers and engineers seem to overlook the operators' required decision latitude and support and actually their role in the design of collaborative human-cobot production units. This might be due to an overemphasis on the technical challenge of getting the cobot to work. Also, both line managers and engineers could ignore human requirements because of production pressures; cobots are expensive equipment and should operate to earn their keep. Finally, one can't rule out the possibility that line managers and engineers might offer inaccurate decision latitude and support to operators because they lack the required HR knowledge and competencies (Gilbert, Winne, & Sels, 2011; Storey, 1995).

However there are three reasons why HR professionals should actively engage in the implementation of cobots in production systems. First, they formally have an advisory role to line management on personnel-related matters (McCracken, O'Kane, Brown, & McCrory, 2017), so it is their job to assure line management provides operators with the decision latitude to directly influence their human-cobot collaborations. Second, because of their human capital development expertise (Datta, Guthrie, & Wright, 2005), HR has the expertise needed to advise line managers on the support they should offer to operators. Third, HR's close proximity to the field of work design (Becker & Huselid, 2010) positions them well to advice both line management and operators on work design characteristics and help them to implement these into their interdependent human-cobot collaboration designs.

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