# Chapter 6
# Intuitive Interaction Between Humans and Robots in Work Functions at Industrial Environments: The Role of Social Robotics

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The social dimension of worker–robot interaction in industry is becoming a decisive aspect of robotics development. Many problems and difficulties of robotics research are not only related to technical issues but are framed by social aspects. Human–robot interaction (HRI) as a specific research field of robotics tackles this issue of intuition. One of the aims is to identify relevant research questions about the possibility of the development of safer robot systems in closer human–machine intuitive interaction systems at the manufacturing shop floor level. This chapter will contribute to understanding the cognitive and perceptual workload for robot operators in complex working systems. The importance of robotics in work life is not only to decrease the physical strains in manufacturing, but also it can increase the need for situation awareness and risk assessment which implies higher perceptual workload and psychological strains. The social sciences approach to such technology assessment is of high relevance in order to acknowledge the dimension of the intuitive interaction concept within social robotics.

## 6.1 Introduction

In recent debates it has become important to understand the definitions of social robots' abilities when they can (or not) be applied to "companion" robots. But the discussion on robots with interaction capabilities in work environments has not been included under the topic of "social robotics", rather, this definition has been

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applied to some type of so-called "cobots" (Colgate et al. 1996). These include 'social interaction with robots' features (perception, sensing, haptic interaction, communication) where people interact with robots that have some degree of awareness of the human in terms of sensing abilities and/or interfaces and abilities to interact and communicate with people. The fact that robots with such abilities are introduced in a working environment means the relation between humans and these machines also evokes the relation between co-workers and the human resource management strategies in a company (Moniz 2014). It relates to a problem of human–machine interaction, and the complexity of the work environment (Bijker et al. 1987). It also becomes a dimension of job design where technical and social criteria must be taken into account for the design of tasks and for the communication process (Huws 2006; Weiss et al. 2009; Bernstein et al. 2007). Meanwhile, in industry there are a lot of examples of machine operators on the shop floor that interact with automated systems using sophisticated communication features. These can include not only data management (robot programme changes, data input and retrieval) but also oral communication features. A robot which is assumed to have 'social' ability will require the ability to perceive its environment (*perception*) and to reason about it (*cognition*), likely including the ability to detect social cues and to reason about the world from the perspective of others. With this in mind, we can also say that the new generation of industrial robots can also be recognised as "robots capable of social ability". But in these cases, the sound communication is not as relevant as is the visual one. This implies that the definition of "language" should be considered as well as gestural communication. In any case, such applications can use "natural interaction" as their most important elements. Nevertheless, the communication capacities are not sufficient to classify these abilities as "social".

Perception has become possible through the use of advanced sensor integration, which can be useful for the human operator by providing information where humans have difficulty such as in collecting data. The cognitive feature is the most difficult one as it could be useful for the human operator when presenting different alternatives during problem-solving. Solutions such as this can be built upon the operator inputs and from knowledge databases that such robots can use. As it is usual for robot cells to be operated by different humans (in the same working group or in different shifts), the knowledge management or reasoning can become useful for task performance and for problem-solving.

The minimization of the cognitive and perceptual workload for robot operators in complex working systems is very important, because it interferes with the task performance and with operational safety. That can be highly relevant when different robots with different roles and different designs are to be used in the manufacturing industry to a larger extent. It is also necessary to investigate the transferability of results from industrial environments to other fields where the introduction of robotics is planned such as in health care, agriculture, mining, underwater, logistics, space operations, inspection, disaster management, medicine and so forth. This chapter examines in the following four sections the role of social robots from the perspective of complex environments, intuitive interaction, cobots, sharing workspace and concluding with some final remarks including consideration of safety issues.

## 6.2 Working with Robots in Complex Environments

Starting from the conceptualisation of 'intuitive interaction with technology' of robotic systems I aim to discuss applications within industrial environments using the 'social' robotics approach. Such a concept should not be only applied to humanoid systems. Complex working environments (CWE) implies the interaction of humans with automated systems, and more often they include robots. This has increased the possibility for eventual malfunctions or even dysfunctions; when they occur the impacts can be severe.

During the 1980s, it was said, for example by J.F. Bard that "in general, robots should be capable of outperforming a person in hostile working environments where noise, vibrations, toxic fumes and other insults are present. Nevertheless, they cannot operate in a disorderly setting. Parts to be handled or formed must be in a known place and have a known orientation" (Bard 1986, p. 102). This means that even in an unstructured work environment which has been called by Bard a 'disorderly setting' a robot cannot operate. There have been important technical and conceptional developments since then, but this assumption continues to be true. A balance should be found between the need to use a robot in aggressive tasks of repetitive action or in hostile environments, and the lower capacity of a robot when compared with the human performance.

In many sectors, such as automobile, electronics and metal engineering, robots have been comprehensively introduced in this way. This means that, according to the International Federation of Robotics (IFR), around 4 million workers around the world have a close connection to robot operation in their work environment (IFR 2013). This has increased the need to consider the social dimension of interaction with technology in these environments. Ergonomics studies became fundamental in all sites where robotic systems had been introduced, but psycho- and sociological inputs are only just beginning in these areas. Indeed, most companies do not have such social scientists on their staff. The solution to close working with robots found by companies is to physically separate the robot cells from the human presence through fences or guards. This can be done without problem in larger companies but in small- and medium-sized enterprises (SME) it becomes a problem due to the lack of available space on-site. Robot manufacturers have started to develop new sensing systems and mechanical and material features that can allow the closer interaction without barriers. Solutions are still under research to develop more "intelligent" systems that integrate such sensor components and allow a more intuitive communication and interaction with humans. New robots with "social" abilities including more complex communication and reasoning capabilities will become more common in manufacturing environments.

Although there is an increased use of social robots for industrial sites, there are still important features that can only be done by human operators. In answer to the question what are the main task roles in a complex working environment one can find the following:

- Operation control
- Maintenance

- Operation monitoring
- Quality control

The performance of tasks must be understood within context of the compliance of the aims of the task in a chain or system of tasks, and the features of its performer (a human or a machine). The question being asked here is: will a human be replaced by a robot? Perhaps even by a robot with increased intelligence and social abilities? My answer, based on my research experience and by literature interpretation, would be no. That answer is also based on the fact that, whenever the more “intelligent” the automatic system of machines becomes, the more complex the problems that will occur. Anyway, the task roles attributed to humans and machines in work environments must be analysed according to all sets of conditions. When tasks are not designed according to the attributes of the performer, the outcomes will not be those that are usually expected. This can happen in automated or in conventional operating systems. Some malfunctions can occur, or even accidents. In other words, “unexpected events” may occur.

To run a batch manufacturing shop on an around-the-clock basis, systems have to be able to respond to unexpected events, such as extra stock, defective material, and premature tool wear out. But Bard added also a curious statement: “Adaptive control, coupled with robots, makes this possible by largely eliminating the need for a skilled operator to be present” (Bard 1986, p. 103). This is one of our key issues. To be precise, it seems that whenever the working environments are more complex or dense, the less it will be possible to “eliminate the need for a skilled operator”.

Some authors also point to the “system responses” which lead to a specific behaviour. But how do systems respond? Do they react, or are they providing information?

In the white paper from the EURON Special Interest Group on Cooperative Robotics published in 2008 it was anticipated that for the next 10 years there would be an advance of “high-level cooperative cognitive skills, while there is a substantial need for improvement of individual cognitive skills, the ability to achieve cooperation in planning, decision making and environment modeling is the key to the development of network robot systems (NRS)” (Saffiotti and Lima 2008, p. 8). To understand this statement one should not translate those “cognitive skills” as being applied just to machines. It would be too naïve to expect such autonomous capacity. It makes sense now when we understand it applied to the interaction with humans. In the same document and about the same expectations, the group also discusses the HRI, stating that:

> Better interfaces to control and interact with NRS will improve usability and make new, broader applications possible. On the one hand, improved distributed cooperative perception capabilities of NRS will make it possible to have effective interaction with people, by understanding different kinds of signals coming from single and multiple persons sharing the NRS space; on the other hand, a scenario with multiple users interacting with multiple robots brings about new challenges that will significantly impact on HRI (Saffiotti and Lima 2008, p. 8).

Probably, the most important question now is to ask “who makes the final decision?”. An answer to this question will enable us to understand how those “systems” are organised.

In general, in the manufacturing production based on automated equipment, the fact that "unexpected events" can occur gains especial importance because accidents, malfunctions or disturbances would impact the working conditions, the expected productivity and all the outcomes. Disturbances with conventional systems are usual and are considered as a cost controllable element, but with automated systems, each time unit without production represents a much higher cost. The production volume per time unit with automation is much higher than with conventional equipment and when those "unexpected events" occur in an automated environment the implications for the economic efficiency (costs, delivery times, quality) are not negligible.

To understand this dimension consider the fact that when skilled operators are taken out of complex production systems it can lead to increased failures and accidents. The implications of those decisions on economic efficiency are at stake; decreased labour costs in an organisation can mean an increased probability of disturbances or "unexpected events", which can become a risk factor. Thus, this can be one of our key issues to be discussed: job displacement and knowledge use.

Another way of exploring these problems further is to answer the following question: are the CWE trustworthy without skilled and responsible workers involved directly? If the answer is positive, that would mean intelligent non-human agents are enough to govern those environments. It would also mean humans should rely on autonomous technology in important decision processes. However, if the answer is negative, a responsible and precautious principle would be to advise humans are always included in the loop. The more complex the working environment would be, the more important it is to involve humans. This assumption brings again the qualification, training and education elements; they become crucial to understanding the problem.

We can also ask if it is possible to develop CWE with unskilled labour? This would mean that in spite of the complexity of the working environment, the qualification is not meaningful. The problem arises when one characterises "complexity". If by complexity we mean just the interconnection of several sets of equipment with some degrees of complexity, but with a high degree of automation, one can conclude there is the possibility to integrate less skilled labour in such environments. These workers could have only minor controlling or monitoring functions and this occurs in several cases, in particular, in larger companies. The problem is that for some "unexpected events" there is no capacity to solve the incident in the minimum possible time. Usually, such occurrences start a complex and large process of decision-making and demands for external experts (technicians, engineers, etc.).

We can conclude that unskilled jobs are better applicable in simpler working environments. Those that require more complex task content also need higher levels of labour qualification. It is easily observable that more complex technologies require tasks with complex contents, and this in turn always demands higher levels of skills and qualifications. Those tasks are usually related to monitoring, controlling, but also require capabilities of fine-tuning programming and maintenance. Operators with those capacities are also able to get more involved in the decision process and in the governance processes of such technology systems.

When we ask if automated systems are "unmanned" systems, what then could be the answer? The correlation would appear to be obvious but it is not supportable. An automated task does not mean that a human should not be present to assist or to be assisted. The cases where fewer humans are present in automated production systems are those in the process industry, but very few can be found in the discrete products manufacturing industry. Thus, the type of production can be a factor that influences the possibility of human involvement in the transformation process.

Finally, which implications for "unexpected events" can reveal the work function in manufacturing? Answering this question means that with the development of more complex production systems, the probability of "unexpected events" occurring is higher. They are especially higher when the systems become unmanned, that is without human control, and is why the prevention of "unexpected events" needs the inclusion of humans in the production process; there becomes a clear "work function". Once there is no work without humans the need to include humans in the automation loop implies the existence of a work function which can be for operation, for monitoring, for control, for maintenance, for programming, for tooling, or for other types of tasks that cannot become fully automated. This means that such working tasks performed by humans must include the capacity of preventing "unexpected events", or in other terms, malfunctions, or even accidents. For these reasons, it becomes so important to think about and design automated systems that necessarily include humans in the loop. Their exclusion can be understandable by a nonconformity with basic management principles. Usually, these type of organisational dysfunctions imply continuous problems in the task performance and in the productivity outputs. They imply also social distrust towards technological developments or even towards innovation policies.

## 6.3 Intuitive Interaction with Robots

The problems mentioned above, like dysfunctions, accidents, and other unexpected events, can be more relevant in the case of robots used in manufacturing environments. As such technology tends to become more sophisticated; even in manufacturing industry the implications for their use are becoming more important while a high volume of automated systems are in operation worldwide. That means the task roles become critical: the qualification for the job must be a factor of system performance, the capacity for programming, controlling and operation becomes even more precise, and overall the intensity of the task increases with the complexity. Great efforts have been made in order to ensure the capacity can deal with such demands. Furthermore, all the operations with most industrial robots became simpler and the interfaces became lighter and easier to use.

The study of applications on industrial environments using robots includes the arguments of intuitive interaction with technology. In a similar direction, the social dimension of worker–robot interaction is becoming a decisive aspect of robotics development. This dimension includes the knowledge necessary to operate machines and systems of machines. It is no longer just a technology problem or a technical challenge but one that is now highly relevant in CWE (robots, autonomous systems, etc.) in the manufacturing industry.

It is also necessary to investigate the transferability of results from industrial environments to other fields where the introduction of robotics is planned (health care, agriculture, mining, underwater, logistics, space operations, inspection, disaster management, medicine, etc.). Such types of new application are not only developed to increase the performance of industrial robots when those developments can also be reapplied with innovations to the traditional robotic systems, but they also became a general issue for all type of robots, including also the professional service robotics. Functions like manipulation, monitoring sensing or vision have been developed by industrial robots and now they are applied in advanced professional service robots.

However, our focus is the type of robots that have been used in work environments which until now have demanded a more or less intensive interaction with human operators. Some technological innovations have been tried in robots that act with a high grade of autonomy or without direct human interference. However, those robots that imply a common workspace with humans can present further technical challenges. The communication features have to be improved, but also all the robotic movement possibilities may interfere with the space where humans have to stand for their work environment. Such interference may cause safety problems and have to be cautiously considered in the programming phase.

The study of robotic applications and their social implications provided clear evidence of this transferability. The main research questions are usually related to industrial applications; now they can also be applied to new types of applications.

Equipped with general information about social behaviour, a robot should be able to detect situations in which certain classes of social behaviours are appropriate and to apply them. Such capacity implies also the feature of intuition in the interaction with humans. In this case, a robot can have an autonomous "reasoning" about how best to achieve its goals in a given social context, and should have the ability to express itself in ways that will help it complete tasks in a wide range of social situations. The frames of goal achievement must be settled in work environments. The higher the capacity is for "autonomous reasoning", the higher must be the intuition for humans to interact with robots. In this situation, a robot can contextualise its messages about its internal representations at this level, and "injects" these communications into the interaction in a "socially acceptable way", according to the MAR definition (MAR 2014). From our point of view, this "socially acceptable way" must be defined in a negotiated way with the working social partners, or at least with the human operators that are working with this type of robots.

## 6.4 Social Robots and Cobots

Recent development of robotics has enabled the emergence of the new concept of social robots as cobots. Although they do not have the same meaning they can be used in similar ways in manufacturing environments, furthermore, it is notable that when one mentions "robotic assist system", it is not only the case of health care examples that we refer to but the concept can also be applied to manufacturing operations.

Cobots are potentially well suited to safety-critical tasks such as surgery and micro-assembly, or those which involve large and powerful interaction force such as automobile assembly (Colgate et al. 1996, p. 433). Cobots are usually considered for a role as helping humans in their operative tasks and not to replace them. This point is important to state because the aim is not the accomplishment of a task with full autonomy, but the coordination of tasks with human operators, thus the interaction features are crucial.

This new technology also created particular approaches to the concept of interactive learning and safety systems of assistive robot. The traditional interactive learning with such system needs to be done on the job and most examples require learning-by-doing procedures, although other examples can emerge. The same applies to the safety measures. Assistive robotics and cobots in general imply that the equipment must operate very close to the human operator in order that he or she can be assisted. Safety rules and procedures can be strict, but those measures have to be included in the design process, and also they must involve the human operator to give information to obtain the best possible results.

## 6.5 Shared Workspace of Human and Robot

As we have explored in the discussion thus far operating a robot, or working together with a robot, means that humans have to share a common space. For safety reasons, a shared workspace between a human and a robot must be considered as a risk factor. Also, "a careful design of so-called intelligent assist systems (IAS) or intelligent automation devices (IAD) and their operating procedures is necessary when physical collaboration between machines and human workers also have to follow ergonomic targets" (Krüger et al. 2009, p. 628).

Sharing a workspace means that the work process must take into consideration the safety areas around robots. Interference between workspaces can occur but only when the robot is switched off thus to ensure safety, the workspaces of humans and robots are strictly separated in time or in space (Lenz et al. 2008). That implies an increased possibility for positioning the human operator with further monitoring tasks without direct intervention during operation. Under such conditions, it is difficult to consider usual robots as co-workers.

The new research developments try to overcome these limitations but to do so the consideration about safety conditions for operation is crucial. "The desired coexistence of robotic systems and humans in the same physical domain, by sharing the same workspace and cooperating in a physical manner, poses the very fundamental problem of ensuring safety for the user and the robot" (Krüger et al. 2009, p. 633). In such environments the control of operation can present limitations, and there is a need for sensor-based surveillance of the workspace.

## 6.6 Concluding Remarks: Safety Is Still a Key Issue

It is important to identify relevant research questions about the possibility of development of safer robot systems in closer human–machine intuitive interaction systems at the manufacturing shop floor level. As I have presented in this chapter, the features of industrial robots have been applied to service robotics and here the developments produced a whole set of innovations such as the increased capacity of human–machine interaction and communication. The autonomy features in professional service robots have enabled new developments on autonomous perception of environments. These developments could even provide autonomous "reasoning" about how the robot can achieve its goals in a given social context. Those new capacities are now applied to manufacturing robotics where the need to interact with humans is very important. However, that interaction implies a further need to focus on the safety issues when designing a production system with robots. As the complexity of work environments increases it can produce the emergence of "unexpected events" where the role of human control becomes more central.

Many authors agree that in the case of physically interacting robot assistants it is obvious that a proven safety standard is of paramount importance (Hägele et al. 2002). But safety is not only a technical feature. Anticipating possible problems or "unexpected events" is mostly a social capability that machines (and in this case, robots) cannot have. In fact, tacit knowledge, qualified and experienced jobs are key elements to ensure and improve safer workplaces with complex environments. Social robotics cannot replace those human workplaces. Robotic manufacturers are developing new safe robots to enable working alongside each other (Wallhoff et al. 2010) that would mean systems with intuitive interaction capacities to ease the co-working feature of those robots. Social robots with higher capacities of interaction and communication have the capacity to become the systems that can fit better into workplaces where human operators perform their tasks. The challenge would be how to also include these social robots in the manufacturing environments.

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