ADVANCED ROBOTICS AND AUTOMATION: WHAT IS IT AND WHAT IS THE IMPACT ON WORKERS?

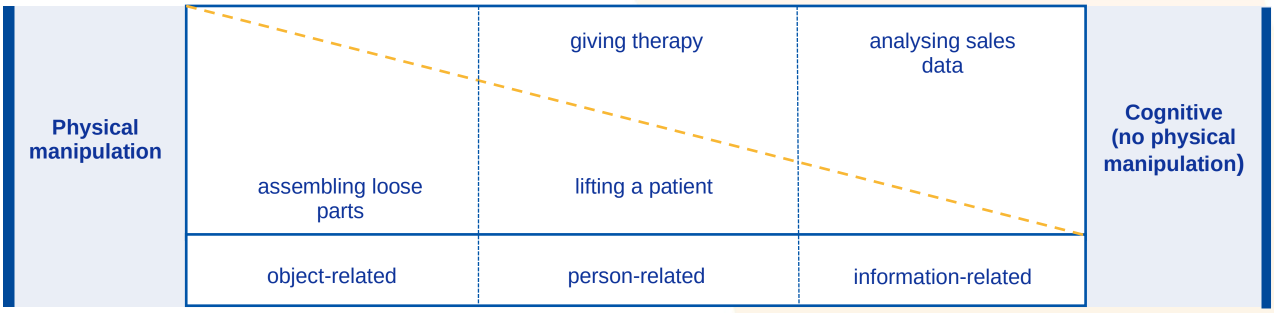
The introduction of advanced robotics in workplaces is clearly changing the structure of work environments. While the automation of different work tasks unlocks benefits and opportunities that improve occupational safety and health, it also creates risks.

This policy brief outlines person-related (cognitive and physical) and object-related tasks for different jobs and sectors that are most affected by robotic system automation. It further gives examples of the opportunities and risks associated with various work environments.

Task types

Whereas traditional automation technologies are mostly used for **routine tasks**, AI-based systems open up the possibility to also perform **non-routine tasks**. The concept of routine tasks follows the idea of how tasks are performed. Furthermore, there are two additional dimensions of tasks: cognitive and manual (physical) tasks. Both cognitive functions (like information processing) and physical actions (like object manipulation) are necessary to accomplish different tasks. As a result, cognitive and physical tasks can be **object-related**, **information-related** and **person-related**[1] to a variable extent.

Figure 1: Task categorisation with example tasks



Each of these three subgroups then further differentiates between the tasks either being a **routine task** for the worker or a **non-routine task**. Within each category, routine and non-routine tasks can theoretically occur likewise. However, within scientific literature, or actual use cases, not every possible combination of categories is present. Physical tasks are mainly object-related, whereas information-related tasks are mainly cognitive.

Regarding advanced robotics, in the literature there are currently no well-established information-related tasks, compared to rather prevalent object- and person-related scenarios. For example, a typical object-related physical task involves the assembly of parts. An example of a person-related cognitive task is teaching. Person-related tasks can be both physical and cognitive. However, nowadays there are available robotic systems that can perform information-related tasks as well. Such systems can for example move autonomously around the workplace, following a hard-coded path, use sensors to collect data from the environment, while having adequate processing power to analyse information, enabling them to suggest actions, take actions or just ring an alarm.

The nature of physical tasks implies, that those most impacted by the automation of AI-based systems are object-related. However, there are also some physical tasks affected by automation that are person-related. One task, which occurs in different sectors (medicine, manufacturing and construction) but is automated or supported by different types of robotic systems, is lifting objects or even people. This is a good example of how the same task is affected across different sectors and their associated jobs. While

[1] Tegtmeier, P. (2021). Informationsbezogene tätigkeiten im digitalen wandel: Arbeitsmerkmale und technologieeinsatz [F 2502]. In *Wissensbezogene Tätigkeiten*. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin. https://doi.org/10.21934/baua:preprint20210115

some tasks are more prevalent or exemplified in a specialised context, but can potentially be applied in other work environments too, some robotic systems are developed to fit a specified task in a specific work environment and allow for limited generalisation. The requirements towards a transportation task are rather independent from the environmental context in which the robot performs, whereas a suture setting surgical robot will only find application in a specific field.

While the continuous development of robotic systems has allowed them to become more flexible in their application, the benefit of specialised machinery compared to a more multi-purpose robot can be seen in these kind of tasks.

Applications of advanced robotics for the (semi-) automation of person-related cognitive tasks

While automation through robotics most commonly is associated with physical tasks, it is the automation of cognitive tasks that has a strong presence in scientific literature. Specifically in the education sector, but also in healthcare and care of the elderly, you can find notable technologies used for the automation of cognitive tasks, like educational and social robots.

Educational robots can be used to support learning in social interactive abilities[2], to enhance students' learning and transfer skills, as well as to increase creativity and motivation. However, up to now, educational robots are mostly used in informal settings like summer schools rather than typical education situations[3]. Automating a teaching situation presents the challenge of creating a system capable of teaching according to the learner's skill level, and not solely based on a predetermined learning path. In recent years, many researchers have worked on the automation of teaching, or specific teaching tasks, through so-called intelligent tutoring robots (ITR)[4], or intelligent tutoring systems[5]. Tasks regarding language education in form of vocabulary and grammatical education[6], teaching of mathematics and science[7] have all been successfully automated. Moreover, while the task of teaching was previously contextualized within schools, it now becomes applicable far beyond that. Specified teaching methods in the form of cognitive training for elderly people[8] or skill training for people with special needs, have become subject to automation, too[9]. This has provided the potential for either independent learning, or better focus of teachers' attention towards individuals with the need for individual support in elderly care. However, the position of teachers in the classroom is still too critical to automate, given the complex social facets of education and interaction with the students.

Apart from educational application, socially assistive robots have also been successfully applied in elderly care for creating positive emotions or therapy engagement[10], as well as for supporting caregivers when nursing patients with dementia or cognitive impairment, taking over reminding functions (e.g., taking medicine) or cognitive stimulation exercises (e.g., singing) through video calls with caregivers[11]. In addition to that, consultation tasks can even be performed by telepresence robots.

The above-mentioned robotic systems are generally described as **service robots**. This broader category of robotic systems can perform a variety of cognitive tasks, not too tightly bound to a specific sector. For example, they can be found in malls, department stores, hotels or airports where they reply to minor customer requests or navigate customers to certain products in different aisles or to their hotel

[2] Hein, M., & Nathan-Roberts, D. (2018). Socially interactive robots can teach young students language skills; a systematic review. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *62*(1), 1083-1087. SAGE Publications. https://doi.org/10.1177%2F1541931218621249

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[4] Yang, J., & Zhang, B. (2019). Artificial intelligence in intelligent tutoring robots: A systematic review and design guidelines. *Applied Sciences*, *9*(10), 2078.

[5] Sottilare, R. A., Burke, C. S., Salas, E., Sinatra, A. M., Johnston, J. H., & Gilbert, S. B. (2018). Designing adaptive instruction for teams: A meta-analysis. *International Journal of Artificial Intelligence in Education*, *28*(2), 225-264. https://doi.org/10.3390/app9102078

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[7] Papadopoulos, I., Lazzarino, R., Miah, S., Weaver, T., Thomas, B., & Koulouglioti, C. (2020). A systematic review of the literature regarding socially assistive robots in pre-tertiary education. *Computers & Education*, *155*, 103924. https://doi.org/10.1016/j.compedu.2020.103924

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[9] Federici, S., de Filippis, M. L., Mele, M. L., Borsci, S., Bracalenti, M., Gaudino, G., Cocco, A., Amendola, M. & Simonetti, E. (2020). Inside pandora's box: a systematic review of the assessment of the perceived quality of chatbots for people with disabilities or special needs. *Disability and Rehabilitation: Assistive Technology*, *15*(7), 832-837. https://doi.org/10.1080/17483107.2020.1775313

[10] Bemelmans, R., Gelderblom, G. J., Jonker, P., & De Witte, L. (2012). Socially assistive robots in elderly care: A systematic review into effects and effectiveness. *Journal of the American Medical Directors Association*,*13*(2), 114-120. https://doi.org/10.1016/j.jamda.2010.10.002

[11] Góngora Alonso, S., Hamrioui, S., de la Torre Díez, I., Motta Cruz, E., López-Coronado, M., & Franco, M. (2019). Social robots for people with aging and dementia: A systematic review of literature. *Telemedicine and e-Health*, *25*(7), 533-540. https://doi.org/10.1089/tmj.2018.0051

room. Especially robots displaying physical human-like features, like a head-torso build and a face, sometimes described as **humanoid systems**, are frequently found in service robots, as they are especially designed for direct interaction purposes.

Applications of advanced robotics for the (semi-) automation of person-related physical tasks

Another prevalent combination of task types is the automation of person-related physical tasks by robotics. This combination can span from assisting in physical interaction with a patient to performing minor **medical procedures** using a robotic system.

Applications of advanced robotics for the automation of person-related physical tasks are especially prevalent in the healthcare sector. As mentioned in the section on the automation of cognitive tasks, there are robotic systems that are used for medical care, for example, by supporting therapy commitment or therapeutic training. Medical robots for the automation of physical tasks refer to systems such as **robotic rollators**[12, 13] in the care of the elderly or impaired as well as to robot-assisted **therapy for balance function** rehabilitation after stroke[14]. Although still in their early development stage, the subgroup of medical robots sometimes referred to as **nursing robots is upcoming**. These specialised robots are capable of **lifting patients** from a bed into a wheelchair or helping them to **stand up**, without the help of a nurse. When using the robotic system, nursing staff won't have to carry the patient's bodyweight. Other typical tasks for nursing robots are to provide assistance in **getting dressed** or to provide physical support while eating. Surgical robots are also used to assist medical professionals in a variety of tasks, such as **setting sutures**. Furthermore, they **support the surgeon** during operational tasks with light, reducing jitter or magnifying structures. Other medical robots can also **draw blood** and **insert intravenous therapy**[15].

Object-related tasks are most frequently automated, however, advanced robots are increasingly able to adjust to their environment, expanding the variety of person-related tasks that can be automated.

Especially healthcare workers, like nurses, can benefit from the capacity of advanced robotics to automate strenuous tasks or to create telepresence working situations. This assistance might provide needed relief for the workers in a sector that is facing worker shortages[16] and extraordinary strain, especially during periods of health crises like the COVID-19 pandemic.

Applications of advanced robotics for the (semi-) automation of object-related physical tasks

The (semi-) automation of object-related physical tasks might be the area most commonly associated with advanced robotics. The automation of this combination of task types can be found in manufacturing or industrial tasks and transportation tasks like warehousing. Many applications are strongly influenced by advances in sensors, actuators, and material or gripper technologies. Innovations in sensor and actuator technologies, for example, allow the identification of obstacles and an appropriate response such as stopping or redirecting movement.

There are numerous tasks with automation potential in these areas. Scientific literature indicates tasks such as **welding**, **assembly**, **paint spraying**, **packaging and arranging**, **cutting**, **moving**, **and sanding** as industrial tasks which can be fully automated by robotic systems[17]. This is in alignment with tasks reported by interviewed experts, who additionally name **heavy lifting**, precise physical activities

[12] Werner, C., Ullrich, P., Geravand, M., Peer, A., & Hauer, K. (2016). Evaluation studies of robotic rollators by the user perspective: a systematic review. *Gerontology*, *62*(6), 644-653. https://doi.org/10.1159/000444878

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[15] Kyrarini, M., Lygerakis, F., Rajavenkatanarayanan, A., Sevastopoulos, C., Nambiappan, H. R., Chaitanya, K. K., & Makedon, F. (2021). A survey of robots in healthcare. *Technologies*, *9*(1), 8. https://doi.org/10.3390/technologies9010008

[16] Michel, J. P., & Ecarnot, F. (2020). The shortage of skilled workers in Europe: Its impact on geriatric medicine. Eur Geriatr Med. Jun;11(3):345-347. https://doi.org/10.1007/s41999-020-00323-0

[17] Iqbal, T., Rack, S., & Riek, L. D. (2016). Movement coordination in human–robot teams: A dynamical systems approach. *IEEE Transactions on Robotics*, *32*(4), 909-919. https://doi.org/10.1109/TRO.2016.2570240

such as **pick and place** tasks and, specifically in manufacturing, the production of small volume assembly items. **Logistics and transportation tasks** are another prime example for robotic automation of physical tasks. Within scientific literature, the aspect of mobility is often addressed separately and independently from the actual robot's purpose. Especially in logistics and warehousing, robots are increasingly autonomous. Nevertheless, they still follow pre-programmed general routes and are programmed in collision avoidance – so there is some intelligence but this is limited and to a specific context. In warehouse environments, this includes loading and unloading of containers, stationary and mobile piece picking tasks and delivery tasks.

Notably, transportation tasks can be specifically found in almost any work environment. Frequently found medical robots navigate autonomously through **hospitals** performing transportation tasks. Already very well-developed autonomous robotic applications can be found in the field of **agriculture**. Examples are tracker systems, satellite-based guidance and weather forecast, humidity detection, and systems indicating when to irrigate or to harvest. Workers in the **industrial** sector have already seen their jobs change through the introduction of robotic systems. There are first examples of fully automated warehouses as well changes to assembly-based production. Workers are likely to continuously face changes in their jobs, with a shift away from repetitive monotonous tasks, towards possible reskilling or more supervisory roles.

Effects on job structure

The increasingly common use of advanced robotic systems to perform tasks will impact the work environment of a significant number of jobs in a variety of sectors. It will shape how, or even if, workers perform tasks that used to be routine to their job, impacting their work environment and, in some cases, altering even the core elements of jobs. Physical and cognitive tasks or jobs with more codifiable tasks will be more rapidly affected. As described by most experts, tasks that will be more likely to be automated are repetitive and routine tasks, especially mid-skilled jobs that entail high amounts of routine tasks. Therefore, the number of mid-skilled jobs might be reduced due to the usage of advanced robotics, simultaneously increasing the number of high-skilled jobs and low-skilled jobs.

In the medical field, we see a number of robotic systems providing specialised support. Other physical tasks that are highly influenced by robotic systems are cleaning or transporting. However, simple physical tasks are most likely to be replaced. Therefore, experts see the **potential of job destruction**, especially among low-skilled jobs with high levels of repetitiveness and routine characteristics. In this context, the '**polarisation' of employment structure** is brought up by experts. The term, which is also prominently addressed in scientific literature, refers to the mechanism that within jobs, tasks which require a mid-skilled profile are impacted by automation, leaving jobs to change in a way that automation will create an increasing number in high-skilled jobs and low-skilled jobs likewise[18]. In a slightly contrasting view, it is noted that many routine physical tasks have already been automated through mechanisation, and that there may be fewer tasks left to automate there. Furthermore, in the opinion of some experts, the use of **collaborative robots** even has the **potential to create more jobs**. These systems have the potential to combine the strength of humans with those of machines. AI can help to coordinate the allocation of work. Teaming humans with robots can increase productivity and therefore benefit the organisation, which in turn is able to invest more and to create new jobs. An example can be seen in cleaning activities. It is assumed that cleaning robots will change the work pace, the ability to decide on a specific task order and maintenance tasks. With such systems, cleaning staff will not wipe floors themselves, but will decide where and when to clean. This is probably the most typical impact of this kind of automation. However, at the same time, these systems can perform the working task of more than one human worker at a time. Consequently, we will be observing a change towards a situation where one human orchestrates multiple robotic systems.

While job loss in specific groups of workers is likely, experts also see the potential for job creation through advanced robotics.

A foreseeable effect on almost any job facing the task of working with advanced robotic systems is the **development of the needed skills** to handle the robotic system. Regarding this development of skills within jobs, the experts describe different requirements depending on the system interaction role. For someone using the technology as an assistive system, it would entail **training** like for any new

[18] Goos, M., Manning, A., & Salomons, A. (2014). Explaining job polarization: Routine-biased technological change and offshoring. *American Economic Review*, *104*(8), 2509-26. https://doi.org/10.1257/aer.104.8.2509

technology, including some form of introduction phase. The rest is done through learning by doing, which is by definition in these kinds of contexts, learning on the job. For people maintaining the systems or further developing them, the question is whether less formalised on-the-job training is sufficient or if they may require further skills training. When designing and developing new systems, not only the skills of direct users need to be considered but also skills of different stakeholders. For example, when deploying technology for smart robotics, it is not only important for those directly working with the robot to understand the system, but also for parties like trade unions, work councils and shop stewards, to function in their position to their best extend. However, addressing this skill level of indirect stakeholder can be quite advanced.

OSH risks and benefits in the work environment

Introducing advanced robotic systems into a workplace does hold the promise and potential of improving working conditions. These new systems will bring change to many workplaces and, depending on how the change process is handled, it may or may not improve jobs. However, one has to consider that mismanaged change can also have adverse effects. Experts describe a process of both upskilling and deskilling in the future. There might be a risk of deskilling when AI-based systems are used to perform specific types of tasks, for instance, in routine tasks such as cleaning, there will be the risk of people losing the skill for this specific task. As the system now performs the task, there is no need to learn and maintain the specific routines. This could lead to possibilities of upskilling by learning new and perhaps more fulfilling tasks; however, in workplaces these types of opportunities will not always exist. At this point, technological opportunities are taken over by decisions that are political. However, technology outside of the social relation per se is neutral.

According to the experts interviewed on the topic of advanced robotics, potential advantages for occupational safety and health (OSH) are mainly seen in relation to the physical dimension, for instance, in the **reduction of physical risk**. Especially using robotic systems on physically strenuous tasks can be beneficial and has the potential for long-term improvements. Physical ergonomics can be improved by **reducing awkward and unhealthy postures** in different environments. In the health sector, for example, nurses experience a rather high rate of injury, mainly caused by the need to lift patients, which could be alleviated with assistive robots. An **improved handling of heavy workloads** and increased efficiency might **reduce perceived stress**. Apart from physical tasks, robotic systems can also help eliminate unfavourable and repetitive cognitive routine tasks, leading to work becoming more interesting for workers. Dynamic systems in which the algorithms may advance their functionalities through AI-based techniques allow a worker-centred optimisation of the work environment through the system.

Although there are a number of systems available aiming at supporting social interaction tasks, like patient therapy engagement, the experts point out that person-related cognitive tasks, or social interaction tasks, are still too difficult to automate. Apart from the degree of standardisation, interpersonal actions have qualitative elements which will hardly ever be achievable by a machine. Moreover, the automation of social interaction tasks has the potential to raise **ethical issues**. As AI-based systems and advanced robotics improve in performing social interaction tasks to some degree but at the same time lack important human-like soft skills, the question arises whether these systems should be used for assistance. On the one hand, a solely human-to-human interaction might be more favourable. On the other hand, AI-based systems and advanced robotics have the potential to widen the access to services like therapy, support or care for patients and clients in understaffed areas. The automation of the above-mentioned combination of tasks can provide opportunities for safer and healthier work environments.

> ***Especially the increased automation of person-related cognitive tasks creates room for ethical considerations.***

Risk assessment

There are risks specifically associated with the use of advanced robotics, but risk assessment tools that cover risk identification and risk analysis for them are currently rare. Guidelines and regulations in this area exist (e.g. ISO 12100[19], ISO/TS 15066[20]), but when it comes to collaborative robotic systems or robotic systems which use AI, these can be too non-specific for the use case at hand. Risk assessment tools also face the additional challenge that the environment in which many cobots are employed might undergo frequent changes. The EU-OSHA recent report[21] on emerging OSH risks associated with digitalisation states that, 'rapid reconfiguration of work processes in response to demands for and expectations about customisation from consumers may mean that the risk profile of a factory changes frequently' (p.53). Accurate and comprehensible risk assessment is vital to ensure OSH, and the lack of tools capable of providing this for advanced robotic systems and their changing environment needs to be considered going forward.

Recommendations

Different types of automation result in different risks and opportunities for OSH. As it is foreseeable that robotic systems will be capable of automating an increasing variety of tasks, consideration must be given to which fields of work benefit the most, and which come with unique risks. Experts agree that the highest potential for OSH improvement through the automation of physical tasks lies in the benefits of physical health, either by removing workers from the environment or by supporting them in their tasks. To ensure that the application of any new robotic system in the workplace doesn't expose workers to new and unforeseen risks, the importance of the introduction process should be stressed. **Risk assessments**, for example, do not only comply with applicable regulation, but also offer the opportunity to structure and carefully consider all relevant aspects of the introduction process. As one can see above, a robotic system may be applied in different contexts to functionally perform the same tasks. However, different circumstances can lead to unique risks, which highlights the necessity to address the working system as a whole with its different components. Furthermore, active change management can create an environment in which workers feel involved in the implementation of robotic systems in their workplace. To prepare workers for the new situation, **training** and the development of relevant skills to handle the robotic system is needed. This can also be used to reskill workers and prepare them for new job structures, new responsibilities and job demands.

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[20] International Organization for Standardization. (2016). *Robots and robotic devices — Collaborative robots* (ISO Standard No. 15066:2016). https://www.iso.org/standard/62996.html

[21] European Agency for Safety and Health at Work. (2018). Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025. https://osha.europa.eu/en/publications/foresight-new-and-emerging-occupational-safety-and-health-risks-associated .

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