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# The Impact of Physical and Mental Stress on the Cognitive Abilities of Employees in Industry 5.0 Manufacturing Environments: A Systematic Literature Review

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## ABSTRACT

Transition to Industry 5.0 reshapes manufacturing work environments by placing human capabilities, wellbeing and sustainability in the centre of technological development. Job tasks tendency to switch from manual handling to cognitive nature as well as workforce ageing, it is critical to understand, the impact of physical and mental stress on cognitive abilities of employees. A systemic literature analysis performed within this study concentrates on relations between employee workload and cognitive performance in Industry 5.0 manufacturing settings, with the aim of identifying research gaps and establishing a theoretical basis for further empirical research. Review of 19 peer-reviewed articles, selected form databases including Scopus, MDPI and ResearchGate, covering the period 2015 – 2026. The findings indicate that physical and mental stress has significant impact on cognitive performance. Conversely, structured rest breaks, ergonomic improvements, physical activity and stress management practices demonstrate measurable positive effects on cognitive function. The results confirm the importance of human-centred workload management within manufacturing environment and highlight the requirement for integrated approach to address human as well as technological factors in the sustainable manufacturing environment.

**Keywords:** Physical load, Stress, Cognitive abilities, Human factors, Industry 5.0

## INTRODUCTION

Today's industrial work environment is characterised by rapid technological development, the complexity of information systems and the transition to Industry 5.0, which focuses on the synergy between people and technology. Industry 5.0 marks a new phase in industrial development, shifting the focus from the automation and efficiency of Industry 4.0 to collaboration, sustainability, resilience and people at the centre of production systems. The Industry 5.0 paradigm emphasises the alignment of advanced technologies with human capabilities to create personalised, customised and sustainable

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manufacturing processes (Shabur et al., 2025). Technological developments in the sector require skills that are referred to as 21st century talents. These enable professionals to work more productively, become more flexible and, at the same time, remain competitive in the labour market. For employers, it is important to find employees with the necessary skills to ensure the successful development of the company (Alojaiman, 2023).

The rapid development of industry in recent years has raised legitimate questions about the impact of these changes on the health, well-being and overall work capacity of employees. By introducing new technology-based systems into the work environment, companies not only improve productivity, reduce costs and promote safe and efficient work performance, but also bring about rapid changes in the daily lives of employees. More and more work tasks are being transformed from active and manual work into passive and cognitive tasks. During the digitalisation of the manufacturing environment, attention must be paid to how changes affect the human work environment – mental workload, fatigue and attention span (Argyle et al., 2021).

At the same time, the ageing of the workforce is a pressing issue: Eurostat data show that more than 65% of people employed in Europe are in the 55-65 age group (Eurostat, 2024). This trend clearly highlights the importance of maintaining and improving the cognitive abilities of employees, as their cognitive abilities directly affect not only safety and the quality of decisions made during work, but also the overall efficiency of the company. Understanding the interaction between physical and mental stress and the cognitive abilities of employees is an essential prerequisite for a sustainable production environment.

The aim of the study is to analyse scientific literature on the impact of physical and mental stress on the cognitive abilities of employees in Industry 5.0 manufacturing environments and to identify research gaps and to establish a theoretical basis for further practical research.

## METHODS

The study analyses the relationships between physical stress, mental stress in the workplace and the cognitive abilities of employees in manufacturing companies. The following databases were reviewed in the selection of theoretical sources: Primo, Scopus, Researchgate, IIETA (International Information and Engineering Technology Association), MDPI (Multidisciplinary Digital Publishing Institute), Open Research Europe. A total of 30 scientific articles were selected on industrial development, the challenges of Industry 5.0, the ageing workforce and the relevance of digital skills, as well as studies on mental and physical workload in the manufacturing environment and its impact on human cognitive abilities, influencing factors and testing methodology. Of these, 19 were selected as most relevant to the content of the scientific publication. Table 1.1 depicts the criteria for inclusion and exclusion of literature sources. The selection was based on studies conducted in an industrial work environment using objective and subjective research methods.

**Table 1.** Criteria for inclusion and exclusion of literature sources.

| Category | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| **Type of publication** | Peer-reviewed scientific journal articles, statistical data, reports | Conference abstracts, dissertations, blogs |
| **Time frame** | Published between 2015 and 2025 | Studies outside the set time range |
| **Language** | English or Latvian | Other languages without English translation |
| **Participants/ Population** | Specific age group, condition, or, species | Irrelevant population, animals (if study is on humans) |
| **Geography/Setting** | Students or employees in the manufacturing sector | Athletes or clinical patients |
| **Availability** | Full-text articles available | Abstract-only, missing data |

## RESULTS AND DISCUSSION

An analysis of scientific literature shows that the Industry 5.0 paradigm emphasises the integration of advanced technologies with human capabilities to create personalised, customised and sustainable manufacturing processes. Unlike Industry 4.0's automated, data-driven and artificial intelligence-driven systems, Industry 5.0 places an emphasis on the human element at the centre of decision-making processes, thus restoring the value of human knowledge, creativity and adaptability in sectors traditionally dominated by automation (Shabur et al., 2025). Industry 5.0 approach focuses on successful collaboration between humans and machines, fostering employee ownership and recognize them as transformation partners (Hein-Pensel, 2025). In the Industry 5.0 work environment, humans are gradually moving from being peripheral equipment operators to full-fledged partners in cyber-physical systems. Collaborative robots, or cobots, serve as work colleagues rather than replacements. They reduce the risk of trauma and ergonomic hazards in production lines, and the sensors and adaptive systems that are often included in the technological equipment of these robots monitor stress levels in real time, ensuring the cognitive and emotional well-being of employees, preventing fatigue and improving concentration (Yanytska, 2025). Rapid industrial development is changing the nature of work and creating new challenges. It is changing the volume and type of work that employees have to do on a daily basis.

On the one hand, professions are changing - new ones are developing and those that are no longer relevant today are disappearing, but on the other hand, this creates unemployment, as not all employees are able to adapt to the new challenges. Therefore, in the Industry 5.0 approach, employees need skills that are referred to as 21st century talents. These skills allow professionals to work more productively, become more flexible and at the same time remain competitive in the labour market. For employers, it is important to find employees with the necessary skills to ensure the successful development of the company (Alojaiman, 2023). The rapid pace of industrial development is evident and clearly involves changes in the working environment. This pace of development and the advent of change have their strengths and weaknesses. On the one hand, the introduction of new technologies increases a company's competitiveness and promotes productivity, but not all companies can pursue such a development strategy due to limited availability of skilled labour and financial resources. The development of Industry 5.0 is largely focused on the development of personalisation and a human-centred working environment. New technologies must be mastered and learned to work with, in order to fully exploit this development opportunity in the real workplace. Another challenge may be the lack of talent or skilled labour and the willingness to learn – to adapt as quickly as possible to Industry 5.0 development trends.

When studying the ageing of the workforce worldwide, one of the latest publicly available studies is the Organisation for Economic Co-operation and Development (OECD) study Employment Outlook 2025. The OECD brings together 38 countries, including 23 European Union member states. The study reports that the expected working life of employees continues to increase and, with more and more people remaining in good health in later years, the potential for extending working life is also growing. In recent decades, OECD countries have seen structural factors affecting labour supply, such as longer life expectancy, increasing female participation in employment and rising levels of education among the workforce, which, together with an increase in the retirement age and stricter conditions for early retirement, have contributed to higher employment rates among older people (OECD, 2026). A study conducted by the University of Padua (Universita degli Studi di Padova) in Italy – a guide to managing an ageing workforce in the manufacturing sector – examined an international manufacturing company with more than 1,500 employees aged 55 and over. 103 interviews were conducted, workplaces were surveyed, and a series of ergonomic risk assessments were carried out using the NAS-TLX, RULA and REBA methods. The study analysed five areas within the company: organisational culture, workplace design and ergonomics, health management, knowledge management and retirement pathways. The study found that there is prejudice against older employees in the workplace, with 38% of employees surveyed reporting high physical strain while 36% reported high mental strain. In the area of health management, a lack of equipment and health promotion programmes was noted, and the lack of knowledge transfer systems and organised succession planning was highlighted. As a result of the study, a practical guide for employers was developed, which included several areas for improvement: management training to overcome prejudices related to the career opportunities of older employees; the development of ergonomics and health promotion programmes – starting with small improvements and motivating employees to incorporate physical activity into their daily routine as well as knowledge transfer and succession planning by creating a structured mentoring programme and platforms where experienced employees can share their knowledge with younger specialists (Katiraee et al., 2025).

It is understandable that an ageing population poses challenges. In order to maintain economic stability, it is necessary to promote the employment and involvement of older workers. At the same time, the development of digital technologies and artificial intelligence has changed the skills required of employees. However, the impact of technological developments is not the same for all employees. For example, workers who have performed intellectual and non-standard work can more easily adapt to the integration of artificial intelligence, while manual workers face a greater risk of automation and, consequently, unemployment in their workplaces. At the same time, production systems geared towards sustainable development are transforming industries and creating new jobs, but these jobs require specialised skills that not all older workers are able to acquire (Eurostat, 2024).

University of Beira Interior in Portugal within the process of implementation of a new LEAN and Ergonomics tool, AgErgoVSM, in a local metalworking company with 500 employees revealed clear differences in the challenges faced by different age groups of employees. It was concluded that older employees mainly suffer from high physical demands at work and limited opportunities for recovery, while younger employees face difficulties in managing mental demands, feeling a lack of control over their work. As a result of the study, improvements were recommended in the workplace – structured rest breaks, age-appropriate stress management training, mindfulness training techniques, as well as ergonomic chairs, footrests and possibly industrial exoskeletons (Alves et al., 2026).

Human perception, memory, concentration, reaction speed, etc. play a decisive role in the acquisition of new skills. All these and other functions of the human brain are referred to as cognitive abilities. The word "cognitive" comes from Latin, "*cognito*" means knowledge, and cognitive functions are the way the brain processes information. Cognitive psychology is the scientific field that studies these processes. It is the science of mental processes related to perception, learning, memory and thinking (Esgate et al., 2004). The sensory function perceives stimuli from the five senses. This function processes visual, auditory, tactile, gustatory and olfactory stimuli, and the information obtained through the senses is then processed. One of the concepts of perception is the identification of previously seen objects from sensory information, such as recognising a lemon only by its smell. Motor skills include various motor activities and skills, such as manual dexterity, performing practical tasks, reaction time and balance. Construction, in turn, involves the ability to copy or create visual objects. Attention and concentration are divided into several subgroups – selective attention is based on perceiving essential information and ignoring non-essential information, sustained attention/alertness is the ability to maintain attention over a long period of time and perform more complex tasks. Memory is one of the largest groups of cognitive functions and is divided into six subgroups. Working memory is the ability to store information for future use; this memory can store information from various senses, as well as verbal and non-verbal information. Working memory has several components, such as executive function, maintenance and manipulation. Manipulation is the retrieval of stored information in a modified form, for example, by selecting only the relevant information from a set of information or changing the sequence. Episodic memory interacts with working memory and has several components: encoding, storage and retrieval. This memory stores memories of what we ate for lunch or what we did the previous evening. Procedural memory stores motor activities or skills. For example, riding a bicycle or writing. Semantic memory is long-term memory that can be stored for a person's entire lifetime. Prospective memory is the ability to perform tasks in the future, a typical example being remembering to take medication at a specific time. Executive function includes reasoning and problem solving. The basis of executive function is control over other cognitive abilities, effectively using resources, solving problems and planning for the future. Processing speed ensures the rapid performance of tasks of varying degrees of complexity. Language skills include perception and production abilities. It is responsible for the ability to follow instructions, identify objects and names (Harvey, 2019).

The cognitive abilities of employees are influenced by the work environment and its conditions, the complexity of the task, and the individual's work capacity and psycho-emotional state. Factors that influence the cognitive work abilities of employees can include the work environment and its physical risk factors – noise, vibration, air temperature and other microclimatic conditions. Cognitive abilities are also affected by physical and mental workload – the tasks that employees have to perform on a daily basis and how much physical strength or mental effort they require. Shift work, the fatigue associated with it, and the ability to adapt to working at night have a significant impact on cognitive abilities. As part of a study conducted by Guizhou University in China, an experiment was organised in which 20 participants tested a CNC workbench in a mixed reality environment while wearing Microsoft HoloLens 2 head-mounted displays under three different load conditions – high load (loud noise of 80.86 dB and 10 pop-up windows on the display), medium load (moderate noise of 72.48 dB and 1 alert window) and a control group with a quiet background –49.54 dB without alert windows. In addition, head and eye movements as well as hand gestures were read from the head display, heart rate monitors were used, and cognitive load was assessed after each task session using the NASA-TLX method. After the experiment, it was concluded that the high load effect prolonged the task completion time by 49% compared to the control group. The results of the NASA-TLX questionnaire showed that a high-load environment increases anxiety and dissatisfaction and reduces the cognitive performance of employees. This study is one of the first to use mixed reality to observe cognitive load in the work environment, and as a result, a prototype warning system was developed which receives signals from sensor data in real time on a head-mounted display, activating the warning system during high stress and offering the employee the choice of taking a break or calling for help (Hou et al., 2025). This experiment highlights the latest trends in workplace research, where modern technologies make it possible to obtain increasingly accurate data on workload and fatigue.

In the working environment of manufacturing companies, people are exposed to various occupational risk factors when learning new technologies, including learning to work with collaborative robots or cobots. A study conducted by the Universidad Iberoamericana in Mexico, which created four different human-robot collaboration scenarios, showed how different models of human-robot collaboration affect the cognitive abilities of employees. When performing work tasks in different scenarios, it was concluded that employees in the role of leader showed lower mental load than those in the role of follower. from which it can be concluded that an employee's mental load is influenced not only by the complexity of the task, but also by the sense of control when performing the work task (Segura et al., 2025). Nottingham Trent University (Nottingham Trent University) study depicts impact of human-robot collaboration on the cognitive load of employees shows that when performing a task in collaboration with a robot, humans are most affected by changes in the complexity of the task at hand. The study used physiological (brain activity measurements), subjective (NASA-TLX) and cognitive ability (reaction time, missed signals) methods. The impact of task complexity was clearly confirmed by brain activity data, reaction time slowing and NASA TLX results. In this study, physiological measurements complement questionnaire data and clearly demonstrate the impact of mental workload on employees' cognitive abilities (Zakeri et al., 2023). In a study conducted by the University of Windsor in Canada on the effects of cognitive overload on assembly workers, 22 study participants were asked to perform a mental task at three levels of complexity – no task, 1 task, 2 tasks. The study shows that the complexity of the task and the increase in cognitive load increase working time and muscle activity. Cognitive overload causes increased physical tension, which over time can contribute to muscle fatigue and the risk of injury (Biondi et al., 2021). Research performed in Germany on the effectiveness of cognitive and stress management training in an industrial environment involved 120 car factory workers who performed assembly line work. The employees were divided into two groups: the first group had increased stress at work and reduced working hours, while the second group had stable working conditions. The results showed poorer results in the first group, for example, the effect of cognitive training in this group appeared only after 3 months, while in the low-stress group it could be observed immediately, but the effect of stress management training was more effective in the first group. This study clearly demonstrates the impact of chronic stress on cognitive function and learning ability, but stress management training could improve the situation (Gajewski et al., 2023). Within a study at a car manufacturing plant in India, an experimental analysis of work postures, shift times and an assessment of their impact on visual inspection station workers were conducted. It was found that the best performance and cognitive function for employees was achieved in a sitting-standing posture during the morning shift (6:00 to 14:00). This study uses a simple practical example to show that small changes in the work environment (adjustable workstations, optimised shift schedules) can have a positive impact on work efficiency (Murugesan et al., 2025). In 2026, a study conducted in the United States on the impact of fitness and exercise on human brain ageing involved an experiment in which 130 participants aged 26 to 58 were involved over a 12-month period. The participants were divided into three groups: a high-intensity aerobic exercise control group, a moderate-intensity aerobic exercise control group, and a health information control group. After 12 months, the results in the control group showed no significant changes, while the high- and medium-intensity training groups showed a significant positive effect – brain age decreased by 0.6 years (Wan et al., 2026). A study of Malikussaleh University (*Universitas Malikussaleh*) in Indonesia on the impact of shift work on employee workload using the NASA-TLX method examined the workload of a rubber processing plant operating in three shifts. The study showed that the morning shift had the highest workload, with employees reporting performance workload, the evening shift reported increased mental workload, and the night shift reported frustration caused by fatigue and sleep disturbances. The authors explain the higher workload of the morning shift by greater control and higher demands – greater stress during working hours. Recommended improvements include monthly rotation between shifts and a more even distribution of tasks, as well as management support during night shifts (Firmansyah et al., 2025).

From the reviewed studies appears that transition towards Industry 5.0 shifts the work from "automation and efficiency" toward human- centred human technology collaboration, that reshapes the overall risk profile. Some transformations within advanced technologies often intensifies mental stress and cognitive load. Across the literature, the most frequently reported challenges are – mental overload, fatigue, reduced or sustained attention, increased errors and lower perceived control – all of which may have direct impact of work quality and safety. Important, that empirical evidence indicates that cognitive strain is not driven only by complexity of the task, but it is also shaped by the workers role and autonomy within the system, the clarity of system feedback, organisational conditions at workplace, time pressure, interruptions and relations between employees. Studies using combined – physiological, behavioural and self-report methods depicts that elevated workload is associated with measurable performance quality reduction. This supports practical requirement for workplace interventions and adaptive support that can prevent cognitive workload escalation before it outcomes in errors or incidents. The second major theme relates to workforce ageing and increasing need to extend work ability across longer careers. Studies shows , that different age groups often face different challenges – with old workers that are most often exposed to higher physical strain and slower recovery, and young employees more often are exposed to mental workload management, lack of control and pressure in digitised work environments. However, studies demonstrates main points for improvement. Even simple ergonomic and organizational adjustments such as adjustable work stations, posture variation possibilities, planned micro breaks, optimized shift schedule and better task distribution can improve cognitive functioning and overall performance. Findings indicate, that chronic stress can affect cognitive functions – trainability and learning efficiency, whereas stress management and resilience-oriented training may mitigate these negative effects and support performance. To summarize , the literature suggests that implementation of Industry 5.0 focuses on human centred technological development, but also systematically pays attention on workload governance, autonomy of employee, training and recovery mechanisms.

## CONCLUSIONS

The advent of Industry 5.0 and technological developments in the manufacturing environment have several positive aspects – they increase company efficiency, boost competition, enable the production of higher-quality goods , provide employees with a tailored working environment, minimises work environment risks associated with equipment-related injuries and reduces the number of occupational diseases, allowing employees to continue working longer. However, there are also challenges – relatively high costs, a long period of time until full integration into the work environment (adjustment, adaptation), a shortage of skilled labour, an ageing workforce, risk of overloading the existing workforce, unwillingness to learn or lack of time due to existing workload, especially in manufacturing, downtime and costs during the transition period.

Studies on modernisation in the workplace cite cognitive overload as the main risk to employees, caused by a series of changes – the introduction and acceptance of collaborative robots, the creation of new models of cooperation, lifelong learning, workplace reorganisation and the creation of new jobs, lack of support during the transition process – all of which are signs of mental workload. At the same time, the introduction of new technologies and the reduction of physical workload also reduce daily movement. Research shows that movement, work posture, working hours and task variability have a significant impact on cognitive abilities. It is important to plan the working environment in such a way that employees have the opportunity to move around and plan structured breaks for exercise, as these issues will become increasingly relevant as the workforce ages. Not only should the acquisition of new technologies be encouraged, but also a healthy lifestyle and physical activity in the workplace. Physical and mental workload significantly affects the cognitive performance of employees in an industrial work environment, and this impact is directly dependent on the intensity, duration and balance of the workload. These findings confirm the importance of human-centred workload management within Industry 5.0.

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