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ERGONOMICS 4.0: DIGITALIZATION PROBLEMS AND OVERCOMING THEM

The article aims to research the impact of digitalization on operator activity. The main concepts and components of the digital environment are considered. The research directions of human-machine interaction in the digital environment are analysed. The problems of digitalization and their impact on the safety and efficiency of the operator's activities are studied. The "Ergonomics 4.0" conception, which combines existing ergonomic trends in the study of the digital environment, creates a single conceptual apparatus and is the basis for developing practical methods for increasing the safety and efficiency of human-machine interaction in the digital environment.

Keywords: ergonomics 4.0, digitalization, operator, digital environment, digital ecosystem, ergonomic thinking.

Introduction

The current stage of society's development is the era of digitalization, which has fundamentally changed human life. Today, many work processes earlier performed by humans have become digital. However, a person remains an essential element of digital systems, and his decisions affect the efficiency and safety of their operation. That is why digital systems need to be studied, and an effective tool for this is ergonomics. However, no classical ergonomics directions, such as physical, organizational and cognitive, but new ones that allow studying human-machine interaction in a digital environment. For example, among them are digital ergonomics, neuroergonomics, information ergonomics, etc. However, the difficulty of their use is in the lack of the systematization of directions by purpose and field of application. Thus, the study of the ergonomics transformation under digitalization conditions will let to systematize new ergonomics directions that will increase the efficiency of their use.

The Problem Formulation

Currently, the activity of a human operator is mainly the search, use, exchange, creation and organization of information in the digital environment. The operator is tense permanently due to the information load, fast pace of work and lack of time, multitasking, responsibility for the decisions made and implemented actions, and unregulated regime. Even after finishing work, the intellectual activity of the operator often does not stop. It does not let a person have a rest. It led to the fact that the organization of human activity in the digital environment became a central issue of ergonomics [1-5]. A worker's comfort, physical and mental health and productivity depend on

whether the equipment and software are designed regarding his psychological, physiological and social needs and characteristics. Therefore, currently, ergonomics aims to find a balance between the digital work environment and the operator's capabilities.

However, there is a **scientific problem**: the necessity to create a general concept combining these directions into a single system of theoretical knowledge and practical methods that increase the safety and efficiency of human-machine interaction in the digital environment.

Aim

The aim is to develop the "Ergonomics 4.0" conception, which will combine the existing ergonomic trends in the study of the digital environment, create a single conceptual apparatus and become the basis for the development of practical methods for improving the safety and efficiency of human-machine interaction in the digital environment.

Discussion of Results

Key components and concepts of the digital environment. Digitization of production influences the issue of labour safety. Business is interested in programs that will let to find effective digital solutions to reduce the risk of hazards and injury rates. Currently, the use of digital technologies is becoming more realistic for increasing the level of production safety. Business has reached a certain level of maturity, which helps to implement new technologies to improve the effectiveness of measures in the field of occupational safety.

Thus, digital technologies have changed the work process and the requirements for its safety. As a result, it led to a new labour concept of "Work 4.0" [6-9].

Work 4.0 is a concept that discusses the future of work in the EU. It describes what changes in the work organization will take place in the coming years in connection with the implementation of Industry 4.0 and digitalization. Work 4.0 focuses on the use of digital technologies and the creation of flexible working conditions. The key provisions of the concept are [6]:

- 1) digital transformation of economic sectors;
- 2) new forms of work through digital platforms;
- 3) reliable data protection system;
- 4) balance of human-machine interaction;
- 5) flexible working conditions;
- 6) changes in organizational structures, etc.

The “Work 4.0” conception pushed the transition of ergonomics to a new development stage. The key trend of this stage is a comprehensive study of the human-machine interaction problems in the digital environment. As a result, several areas of research and analysis of human-machine interaction in the digital environment have been created within the framework of ergonomics (Fig. 1).

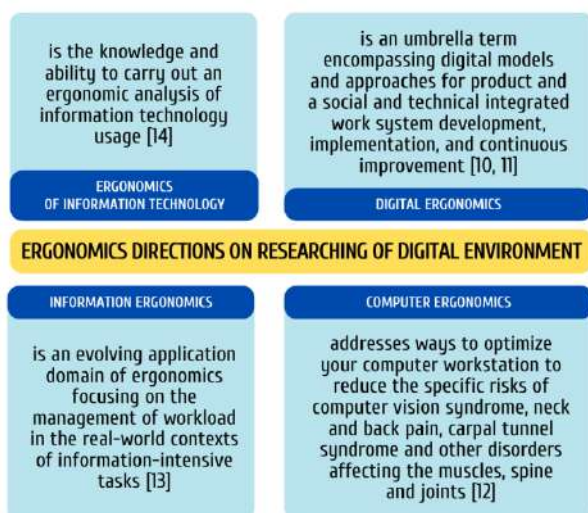


Fig. 1. Ergonomics directions on researching of digital environment

These directions study human-machine interaction in the digital environment but from different positions. Thus, digital ergonomics creates digital models of human interaction and information systems. Its purpose is to optimize the operation of the human-machine system by analysing a previously created virtual model of the functioning of this system and forecasting the occurrence of problems and shortcomings of functioning. In such a way, researchers detect system flaws and minimize their negative consequences at an early stage.

Computer ergonomics focuses on the practical training of users of information and communication technologies (ICT) in the rules of their operation. After

all, it is essential not just to ensure the appropriate technical level of workplace equipment but teach the user rules that contribute to maintaining health.

Information ergonomics aims to manage the workload of the ICT user in the conditions of performing information-intensive tasks. Today, the performance of work tasks increasingly depends on the creation, search, use, exchange and organization of information. At the same time, the operator works in a multi-channel and information-rich working environment. Thus, information load management has become one of the essential issues in ensuring the efficient operation of the human-machine system, which pushed the information ergonomics development, which optimizes information flows in the human-machine system.

And one more direction is ergonomics of information technology (IT). It aims at developing the principles of creating ergonomic digital products. UX/UI design uses these principles.

Thus, in recent years, new directions have appeared in ergonomics that study human-machine interaction in a digital environment and develop measures and tools for optimizing this interaction. Let’s consider the conceptual apparatus of the ergonomics concept in a digital environment.

Let’s start with the “digital environment” concept and its components. It has the following definition: the digital environment is an integrated communication environment in which digital devices exchange information and control their content and actions [15]. This concept includes devices that transmit and receive information and various software types for working with them. That is why the digital environment is the basis of Industry 4.0 and digital ecosystems (Fig. 2).

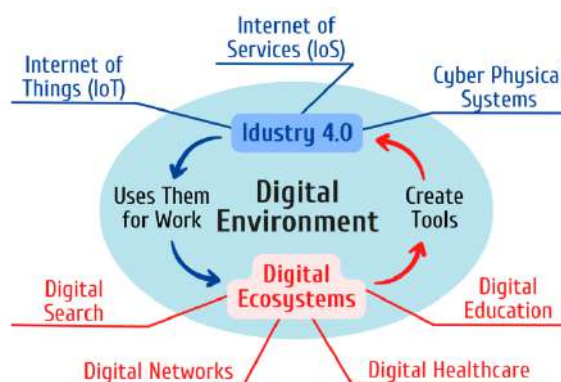


Fig. 2. Components of the digital environment

Digitization has influenced the transformation of the concept of “workplace”. Working in a digital environment has made it possible to make workplaces mobile due to the possibility of an operator staying

online permanently. This trend is spreading quickly and has positive feedback from employees and employers. A digital workplace is a virtual equivalent of a physical workplace that requires proper organization, use and management. It has to guarantee the operator's efficiency and create favourable working conditions for him [7].

The digital workplace combines most of the technologies used to work in a digital environment. Digital workplace allows:

- 1) reduce the number of routine operations and raise the level of work creativity;
- 2) increase the involvement of employees in the work process;
- 3) apply new forms of employee communication (including through social networks);
- 4) implement new forms of distribution of work tasks, etc.

Digital workplaces contribute to the development of digital competencies. Their totality represents an individual's ability to effectively and safely choose and use ICT in work [16]. Digital competence significantly affects the efficiency and safety of the operator's work, and it becomes a priority in the transition to digital workplaces.

One more concept that needs research is the human factor. Currently, technical systems have high reliability; thus, we must focus on the human causes of accidents. According to statistics, up to 80% of accidents happen because of a person's action or inaction. In other words, accidents happen due to the human factor.

The digital environment features determine the transformation of the human factor components. Considering this, the essential elements of the human factor are the work task, the operator's individuality and the work process structure.

The work task in the digital environment includes the characteristics of the activity and its ergonomic requirements, the operator's workload, the work environment and workplace conditions, technical equipment, work procedures and instructions. Work tasks should be designed according to the principles of information ergonomics, digital ergonomics and IT ergonomics considering the operator's capabilities and limitations.

The operator's individuality includes competence, skills, emotional intelligence, understanding of the digital environment specifics, resources, risk perception and attitude towards it. This component has a complex impact on operator behaviour since some operator characteristics do not change (for instance, temperament), while others (skills and attitudes) do.

The work process structure includes a safety culture, provision of resources (financial, technical, human), the level and methods of workers'

communication, work organization and operators' rest regime. The work process structure has an impact on both operator behaviour and group one.

Human factor management in a digital environment will help prevent work errors and accidents. Let's analyse the components of the human factor and what it can be done to reduce its manifestation [17, 18]:

1) communication between workers is the basis of the activity of any organization. A problem solution often can be found due to communication. Thus, it is essential to establish communication between operators, which will increase the efficiency of their work in the digital environment and reduce the level of erroneous actions;

2) emotional intelligence. Working in a digital environment is accompanied by stress and emotional tension. These problems are often overlooked because there is an extremely high focus on mastering new technologies and improving processes. People with well-developed emotional intelligence can independently identify such conditions and overcome them timely. However, there are few such workers. Most often, operators do not have this skill. Thus, it is necessary to develop emotional intelligence to increase the operators' safety and efficiency in the digital environment;

3) understanding the specifics of the digital environment. One more human factor component is the operator's understanding of the importance and inevitability of constant changes in the digital environment. Often, organizations simplify the processes of digital transformation of the work-flow to the level of the statement: "We are replacing old technologies with new ones". It leads to a decrease in the operator's efficiency and the occurrence of errors. It happens because the operator does not understand why he needs new digital technology, whereas the previous one had done the necessary functions. That is why it is essential to formulate the goal of the following digital transformation stage and bring it to operators;

4) safety culture is a set of safety beliefs and values that all workers adhere to. It is a phenomenon that reflects current social processes and is formed in the process of the activity. Its development level means a person's understanding of the importance of creating safe working conditions at the workplace [19]. That is why the operators' safety culture must evolve with the technological growth of the organization. It will allow operators effectively adapt to continuous digital transformations. That, in turn, will reduce errors and increase the reliability of the operator's activity;

5) resources are all that is significant for a person and help to adapt to difficult life situations. In other words, these are any material and non-material objects, facilities or phenomena that a person uses to increase the effectiveness and safeness of activity [20-23]. Two

aspects are essential in the operator's resources issue. The first aspect is providing the operator with access to resources and the possibility of their development. The second is the development of the operator's resource management skills. The second aspect has the most influence on the operator's efficiency and safety in the digital environment.

The human factor is associated with risk since a person often has to act in a situation of uncertainty and, therefore, take risks. The sources of indeterminacy in the digital environment are:

- 1) continuous digital transformations;
- 2) lack or excess of working information (that is why the employee uses the method of trial and error and takes a risk);
- 3) operator's individuality.

The most difficult to research is the operator's individuality. And because digitalization focuses on reducing the number of routine operations and increasing the creative component of the employee's activity, the individuality's influence grows significantly. Therefore, we should use an anthropocentric approach to research the digital environment.

Digitization problems. The development of digitalization is becoming a source not only of new opportunities but also of severe threats to society. Thus, the Organization for Economic Cooperation and Development report states that digital technologies can be destructive. Eventually, it will negatively affect productivity, employment and people's well-being. The UN also recognizes digitization as one of the four main dangers threatening humanity shortly. Also, the World Bank points out that digital technologies are spreading, and digital dividends are not meeting people's expectations. Thus, on the one hand, digitalization creates space for human-machine interaction development but, on the other hand, builds problems that need to be studied. Let's consider the most significant digitalization problems which influence human-machine interaction:

1) irregular working hours and workload. The blurring of boundaries between work and private life due to the proliferation of work-from-home opportunities. An increased workload due to the need for constant professional development to obtain a job;

2) healthcare problems. Shifting investments towards digital transformations. A decrease in the significance of the use of health-preserving technologies. It is especially felt under remote work when there is no external control over the quality of the workplace organization and the rationality of working time distribution;

3) specific consequences. Digital autism and hyper information of the environment due to the loss of social skills, which causes the inability to think

critically and the development of clip thinking (the perception of the surrounding reality as a sequence of unrelated things and not as a homogeneous structure that exists as an interconnected system);

4) increasing probability of technological failures and technogenic disasters;

5) the threat of cyber attacks. With the introduction of a hybrid work environment permanently, it is clear that the probability of cyber attacks will increase many times shortly. The consequences of cyber attacks can lead to significant financial losses and psychological person's trauma;

6) automation problems. Some automation solutions may inadvertently introduce software incompatibilities or add a layer of redundant operational complexity that increases human load. AI-based automation tools can also pose human risks that are often difficult to predict in the long term due to the ever-changing nature of the technology itself.

The consideration of the essential components and concepts of the digital environment and the problems of digitalization demonstrates the importance of creating a new ergonomic conception that will combine the existing ergonomic directions in the study of the digital environment, create a single conceptual apparatus and become the basis for the development of practical methods for improving the safety and efficiency of human-machine interaction in the digital environment. In our opinion, such an ergonomic conception can be represented as an environment of ergonomic thinking, the various components of which are united by the idea of ergonomic thinking in the following way (Fig. 3).

Ergonomic thinking is one of the forms of systems thinking and recognition of the exceptional priority of human-machine interaction problems.

The current state of ergonomics is a shift of emphasis on the adaptation of humans to technology or the adaptation of technology to humans to the formation of a "human-machine" symbiosis. The main idea of ergonomic thinking is the laws of mutual adaptation and transformation.

That is why the development of ergonomic thinking in future engineers should be given considerable attention because it is a system of views of an individual on the development of complex human-machine systems and the role of man in them; it is an understanding of the complex processes of human-machine interaction; the ability to predict risks in these systems and plan the development of systems with a preliminary consideration of these risks.

Conclusions

The methodological base of ergonomics needs a conceptual update since the approach to work has changed due to the large-scale introduction of the digital

environment. New types of activity have appeared. It requires the introduction of new concepts.

The tendency to implement changes in ergonomics is to create a new concept that combines the existing ergonomic trends in the study of the digital environment, creating a single conceptual apparatus and the basis for practical methods for improving the safety and efficiency of human-machine interaction in the

digital environment. Therefore, the research proposes the “Ergonomics 4.0” conception, which combines existing ergonomic directions in the study of the digital environment and, in our opinion, creates a single conceptual apparatus and basis for the development of practical methods for increasing the safety and efficiency of human-machine interaction in the digital environment.

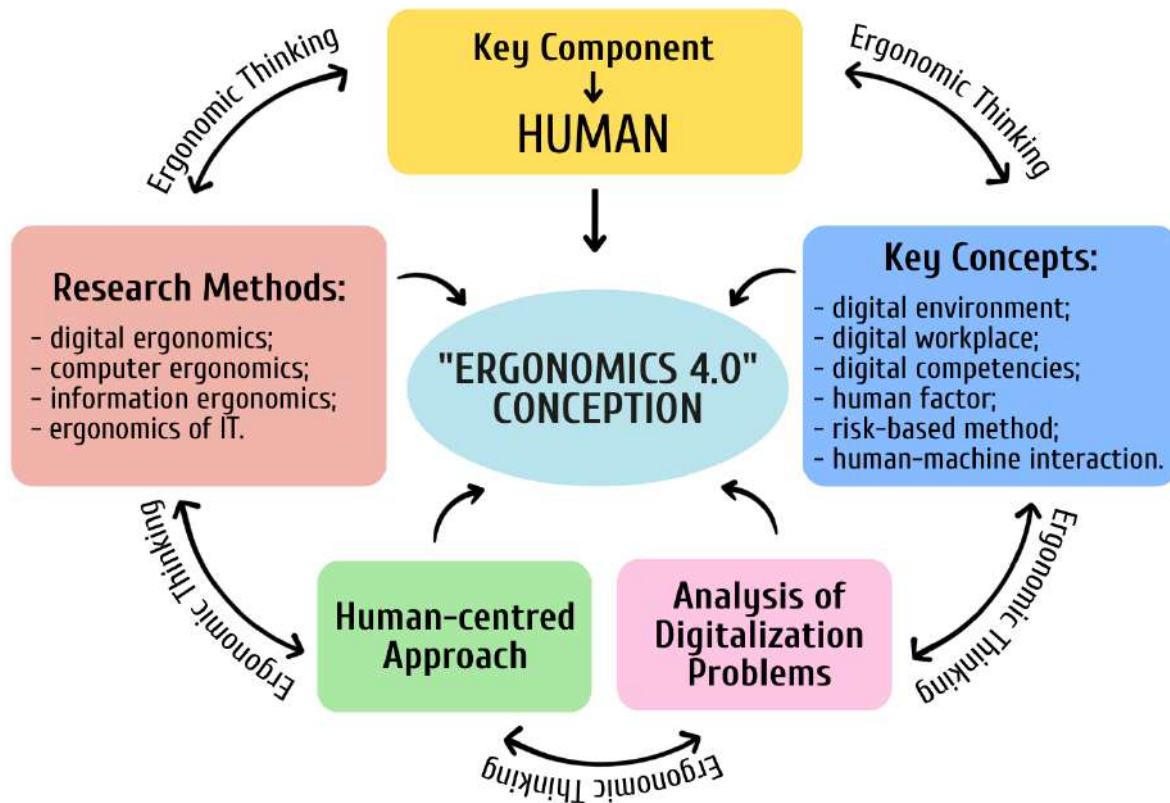


Fig. 3. “Ergonomics 4.0” conception

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ЕРГОНОМІКА 4.0: ПРОБЛЕМИ ЦИФРОВІЗАЦІЇ І ЇХ ПОДОЛАННЯ

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Поточний етап розвитку суспільства – це епоха цифровізації, яка докорінно змінила життя людини. Сьогодні багато робочих процесів, які виконувала людина, стали цифровими. Однак, не дивлячись на це, людина залишається ключовим елементом цифрових систем і її рішення впливають на ефективність і безпеку їх функціонування. Саме тому цифрові системи потребують вивчення і ефективним інструментом у цьому є ергономіка, але не її класичні напрями, а нові, які дозволяють вивчати людино-машинну взаємодію у цифровому середовищі. Серед таких напрямів, наприклад, цифрова ергономіка, нейроергономіка, інформаційна ергономіка та інші. Проте складність їх використання полягає у відсутності систематизації напрямів за призначенням і галуззю застосування, тому дослідження трансформації ергономіки в умовах цифровізації дозволить систематизувати нові напрями ергономіки, що підвищить ефективність їх використання. Мета роботи – розроблення концепції “Ергономіка 4.0”, що поєднає наявні ергономічні напрями з дослідження цифрового середовища, створить єдиний понятійний апарат і стане підґрунтям для розробки практичних методів з підвищення безпеки й ефективності людино-машинної взаємодії у цифровому середовищі.

У статті проаналізована методологічна база ергономіки на поточному етапі розвитку і на підставі цього встановлено, що вона потребує понятійного оновлення, оскільки останніми роками підхід до праці змінився через масштабне впровадження у діяльність працівника цифрового середовища. З'явилися нові “цифрові” види діяльності, що, безумовно, потребує введення нових понять. Досліджені і проаналізовані проблеми цифровізації, адже її розвиток є джерелом не лише нових можливостей для діяльності і розвитку оператора, але й загроз для його безпеки. Таким чином, необхідність впровадження змін в ергономіку обґрунтована двома факторами: 1) змінами умов діяльності оператора через її масштабну цифровізацію; 2) наявністю негативних наслідків цифровізації, які створюють загрозу для безпеки оператора. У роботі показано, що втілення таких змін можливе через створення нової концепції в ергономіці, яка поєднає наявні ергономічні напрями з дослідження цифрового середовища, створить єдиний понятійний апарат і стане підґрунтям для розробки практичних методів з підвищення безпеки й ефективності людино-машинної взаємодії у цифровому середовищі.

На підставі проведеної роботи у статті запропонована концепція “Ергономіка 4.0”, що поєднає наявні ергономічні напрями з дослідження цифрового середовища і, на наш погляд, створює єдиний понятійний апарат, а також може бути використана для розробки практичних методів з підвищення безпеки й ефективності людино-машинної взаємодії у цифровому середовищі.

Ключові слова: ергономіка 4.0, цифровізація, оператор, цифрове середовище, цифрова екосистема, ергономічне мислення.