

ОГЛЯДИ, ЛЕКЦІЇ

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CURRENT STANDARDS FOR THE ERGONOMICS DESIGN OF SOFTWARE FOR VISUAL DIGITAL ASSISTANCE SYSTEMS IN GERMANY

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The aim of the research – considering the industrial changes in times of Work 4.0, new digital solutions must be implemented. The systematic overview of the existing standards should contribute to the human-centred design of assistive systems and provide support for the development and evaluation of new digital assistance systems.

Materials and methods of the research. Within the framework of the joint project «3D-Montageassistent» (funded by BMBF), various databases were searched for standards and guidelines for the ergonomic design of digital assistance systems existing in the national and international area.

Results. With regard to the objectives, the standards series DIN EN ISO 9241 «Ergonomics of human-system interaction» as well as DIN EN ISO 26800 «Ergonomics – General approach, principles and concepts» and DIN EN ISO 6385 «Ergonomics principles in the design of work systems» stand out in particular.

Conclusions. A multi-professional cooperation forms the current path of occupational medicine. The individual is placed at the centre of attention for the design and is promoted preventively. Some standards already exist for the human-centred design of digital assistance systems, but the development of new legislation cannot keep pace with the speed of development of new technologies. For the harmless use of visual digital assistance systems, the deficits must be addressed.

Key words: assistance systems, ergonomics, standards, work 4.0, usability

Introduction

Due to industrial changes directly related to Work 4.0, the need for digital assistance systems is increasing [2]. Work tasks are becoming more and more complex. The variety of products to be manufactured is growing. An increase in flexibility and more project-based work with simultaneously shortened product life cycles lead to high demands on the cognitive performance and resilience of employees.

In order to be able to meet these increasing demands, there is, among other things, increasing technical support and digitization in the direct work environment. Digital assistance systems encompass a wide range of innovative information and communication technologies and applications that support employees in their work, for example in industrial assembly, in complex production and logistics processes, in rule-based planning processes in production planning, or in maintenance and servicing. The individual is placed at the centre of attention for the design and is promoted preventively [1].

Digital assistance systems are intended to contribute to the solution of complex tasks and help employees with the processing of the work task with the help of various support mechanisms. Inevitably, digital assistance systems based on software lead to human-machine interaction. The aim is to reduce error rates, thereby improving product quality and increasing work and process safety.

In particular, the negative effects of stress on the employee in the form of visual and psychological strain should be kept as low as possible, which is why human-centered product development of digital assistance systems is increasingly coming into focus. This means that the focus of the system to be designed is the working human being as the main factor and integral part [3].

The question of existing standards and guidelines for the ergonomic design of the user interface in the development and implementation of digital assistance systems arises for technical developers as well as for occupational physiologists, occupational scientists, safety engineers and company physicians.

In this context, the standards largely correspond to the design objective of the German Occupational Health and Safety Act and, above all, take up the intention of the concept of the «humane design of work» (§ 2 ArbSchG) as part of the occupational health and safety measures [3].

The aim of the research – the systematic overview of current standards for the ergonomics design of software of digital assistance systems is intended to contribute to the development and assessment of such systems with a human-centered approach, taking into account current standards and recommendations of relevant literature.

In doing so, the goals of humanization and improvement of the efficiency of work are pursued. This includes the aim oriented and efficient fulfillment of tasks and processes that are becoming more and more complex.

Materials and methods of the research

The focus of the systematic research is on answering the question for practice, which assistance can be used in the development and assessment of the ergonomic design of digital assistance systems. For this purpose, research is carried out in various databases, such as those of the German Institute for Standardization (DIN) and the Association of German Engineers (VDI) for national and international standards and guidelines.

Results of the research and their discussion

Whether a system is fit for use always depends on the context. For this purpose, the properties of the system or software, the formulated goals, the work tasks, and the characteristics of the users must be considered (Figure 1). The overall context must be coherent.

The relationship between the three categories task, user and assistance system or software can be described as a triangular relationship and forms the so-called «ergonomic triangle». If the triangular relationship is in balance, then usability or software ergonomics is also correct [4].

In particular, the DIN EN ISO 9241 series of standards «Ergonomics of human-system interaction» contains many useful tips and procedures in product development and human-friendly design of visual digital assistance systems and should therefore be given special attention. The standard, which

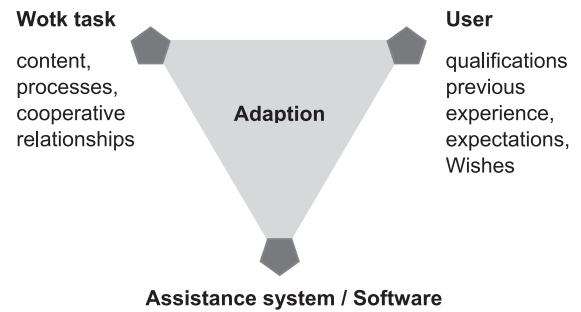


Figure 1. Ergonomic triangle to illustrate the triangular relationship between the task, the user and the assistance system (Software-Ergonomie – Forbit)

was known until 2006 as «Ergonomic requirements for office activities with visual display terminals», is still the international standard today. Table shows the basic structure of the individual parts of DIN EN ISO 9241.

On the one hand, the series of standards describes guidelines for human-computer interaction and, on the other hand, defines principles for the working environment, hardware and software. The objectives are to prevent damage to health and to optimize the usability of digital processes (Figure 2) [5].

DIN EN ISO 9241 – 11 provides the basic framework for the other standards in this series, or forms the overarching «roof» in customer-centric product development. DIN EN ISO 9241 – 11 can be under-

Table

Structure of ISO 9241 – Ergonomics of human-system interaction (Deutsches Institut für Normung e.V.)

Part	Title
1	General Introduction
2	Guidelines for task design
11	Usability requirements
20	Accessibility and Human-System Interaction
21–99	Reserved Numbers
100	Software ergonomics
200	Processes of human-system interaction
300	Displays and display-related hardware
400	Physical input devices – Ergonomic principles
500	Workplace ergonomics
600	Ergonomics of the working environment
700	Control centers
900	Tactile and haptic interactions

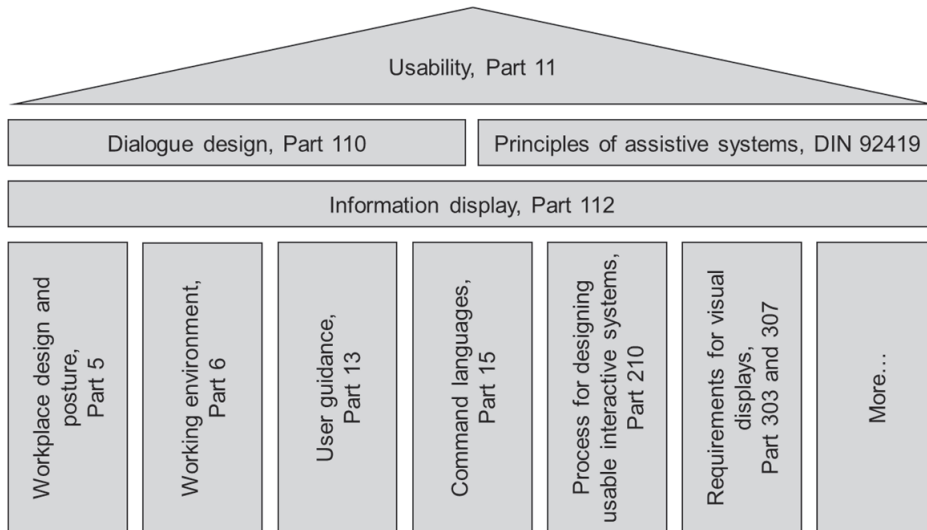


Figure 2. Structure of DIN EN ISO 9241 – «Ergonomics of human-system interaction»

stood as a guide for identifying relevant aspects of work tasks and the working environment [6]. Three guiding criteria are used to record the extent to which a product can be used by specific users in a specific context to achieve defined goals effectively, efficiently and satisfactorily [6].

DIN EN ISO 9241 Part 110

Part 110 of the series of standards on the principles of dialog design is supplemented by the principles of assistive systems in DIN 92419. The objectives pursued are easy operation of user interfaces of interactive systems, such as web pages and software, by the

respective users. Part 110 uses seven quality criteria to describe dialog design for human-machine interaction (Figure 3).

Here, task appropriateness includes support for simple and direct goal achievement of the work task, e.g., by minimizing interactions that are unnecessary for the work task. A self-describing system conveys information to the user about the expected input through help, feedback, and/or prompting messages. Good self-description capability also includes self-explanatory symbols. A dialog flow and the activity of a system should be able to be influenced by the user not only started, but also in its direction and speed up

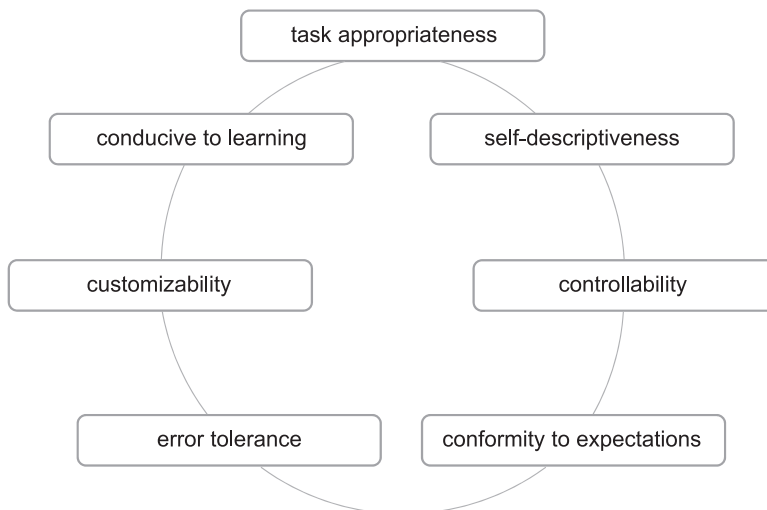


Figure 3. Principles of dialogue design according to DIN EN ISO 9241 – 110.

to the desired goal. Expectation conformity means the fulfillment of the user's expectations of the system based on the work task and his previous experience with other products. Consistency of dialog and generally accepted conventions should be observed. The system should go beyond a tolerant reaction to errors to point them out to the user and allow easy error correction in order to achieve its work goal.

Adaptability to, for example, individual needs, knowledge, and habits of the user can be found under the principle of customizability. In addition, a system should support and guide its user in learning the functionality and operation of the dialog system, e.g., through icons, dialog boxes, or staggered menu levels [7, 8].

DIN 92419

DIN 92419 describes general principles of ergonomic design of assistive systems and is designed as a future part of the DIN EN ISO 9241 series. The standard part 110 is supplemented by the 6 principles:

- acceptance
- safety, security and privacy
- optimization of consequential stress
- controllability
- adaptability
- perceptibility and recognizability.

The principles for development are independent of a specific technical solution or interaction technique and provide a framework for use in the ergonomic design, analysis and evaluation of assistive systems. The principles of dialog design from DIN EN ISO 9241 – 110 are also valid for the ergonomic design of assistive systems if a dialog exists between the user and the interactive system. However, it should be noted that assistive systems do not always require such a dialog (e.g. exoskeleton or pacemaker).

With the help of the described principles, assistive systems should avoid user problems. User problems include incomprehensible or unforeseeable consequences of use, «paternalism» of the user by the system, dangers and impairments resulting from use, rejection or lack of acceptance, and involuntary disclosure of personal data. The weighting of each individual principle with the goal of ergonomic design depends on the requirements of the intended system user as well as on the respective environment and the interaction technology used in each case as well as the task. Weighting is necessary because the princi-

ples compete in their applicability depending on the user context [9].

An assistive system is accepted if the user can recognize an added value to the usability and an overall positive user experience results. Recommendations for achieving this experience are, on the one hand, attention to the joy of use. On the other hand, the added value beyond functionality should be focused on during development. It should be taken into account that different users may derive different added value from the same assistive system. Further recommendations for acceptance arise for the design of functional and external components, functionality and individual sensation. Functionality should inspire confidence in the user (e.g., mode of operation should be comprehensible and predictable), and sensation should be as unobtrusive as possible in the respective living environment.

There must be no negative consequences for the safety, health and privacy of a user during intended or foreseeable use. Recommendations at this point are, for example, a prevention of manipulation of the functionalities by unauthorized persons. In addition, intended use should be reliable and safe without causing harm.

The use of assistive systems usually results in a new load structure; this should be optimized for the respective user on the basis of the consequential stresses. Recommendations in the standard are the avoidance of disproportionate stresses and active use of the load for the user's own advancement.

Users should be able to control an assistive system, i.e. to view its status and influence its progress at any time. Recommendations of the standard are the determination by the user of the basic influence and its scope.

An adaptation of the functionality to the respective context of use serves the adaptability of the system. This can be, among other things, the degree of support, as well as privacy settings.

If the entire components and information of an assistive system can be detected and interpreted by the user, the perceptibility and recognizability required by the standard are fulfilled. It should be possible to perceive the current state and prompts for a dialog at any time via at least two different senses. For the hardware, a clear possibility of differentiation is recommended, through the appropriate design of the operating elements and the information displayed [9].

DIN EN ISO 9241 Part 210

Another decisive role of DIN EN ISO 9241 is played by the human-centered design process (Part 210: Process for designing usable interactive systems). In this part, the context of use and the requirements for use are defined, and design solutions for meeting the requirements for use are developed and evaluated step by step with the participation of the users. This approach supports the achievement of the goal of the highest possible acceptance by the user for the system to be developed. In addition, the approach increases effectiveness and efficiency, accessibility and sustainability, and improves both subjective well-being and user satisfaction. Possible adverse effects on human health, safety, and performance that arise from the use of the system are counteracted by the human focus.

The standard part is primarily aimed at the management of processes for the design of hardware and software in order to define human-centered design activities effectively and in a timely manner. Part 210 complements existing design concepts and can be incorporated into different approaches to applications. However, this part only provides an overview of human-centered design activities. Neither details of procedures and techniques nor health and safety aspects are covered in detail. The authors of standard part 210 refer forcefully to the possible application of human-centered procedures to the entire system life cycle. This results in incidental benefits to the full life cycle cost of the product, system, or service including conception, design, implementation, sustainment, use, maintenance, and ultimately decommissioning. Furthermore, it clarifies the role of iteration in the overall design process, not just in evaluation. Lastly, the standard adds guidance on sustainability, reinforced by human-centered design, and includes a checklist for assessing applicability and conformity [10].

DIN EN ISO 9241 Teil 112

Another important component of the series of standards is the fundamentals of information presentation (Part 112). In connection with the software-controlled presentation of information by means of user interfaces, ergonomic design principles are established for the three main sensory modalities normally used in information and communication technology. The three main sensory modalities include visual, auditory, and tactile/haptic stimuli. The principles listed are

valid for the perception and comprehension of presented information and are to be applied to both the analysis and the design as well as the evaluation of interactive systems [11].

Only when the conditions listed so far have been met, further aspects should be considered, such as the requirements for electronic visual displays (Parts 303 and 307) [12, 13], user guidance (Part 13) [14], command languages (Part 15) [15], working environment (Part 6) [16], workplace design and posture (Part 5) [17], and other guidelines for the design of novel digital assistance systems (compare Figure 2) [5].

In addition to the DIN EN ISO 9241 series of standards, other higher-level guidelines for the development and use of digital assistance systems can and must be consulted. These include, for example, DIN EN ISO 26800 entitled «Ergonomics – General approach, principles and concepts» and DIN EN ISO 6385 «Principles of ergonomics for the design of work systems».

DIN EN ISO 26800

DIN EN ISO 26800 is superordinate to the DIN EN ISO 9241 series of standards specified for human-system interaction. Among other things, this serves as a reference standard for standards developers concerned with ergonomic aspects and provides a basis for other, more detailed, context-specific international standards on ergonomics. Accordingly, this standard describes general ergonomic principles, concepts and approaches and refers to other relevant ergonomics standards. Applicable to the design and evaluation of tasks, activities, products, tools, equipment, systems, organizations, services, facilities, and environments so that they are adapted to people's characteristics, needs and values, abilities, and limitations.

Among the principles are the human-centered approach (intended target population, intended outcome, environment) and criteria-based assessment, while the concepts of ergonomics discuss the system concept, the stress-strain concept, usability and accessibility. DIN EN ISO 26800 provides a holistic framework that brings together the key principles and concepts of ergonomics in one document. As a result, this provides a comprehensive overview of how ergonomics is applied. At the same time, the aim is to improve safety, performance and usability while at the same time safeguarding and promoting human health, well-being and improving accessibility [18].

DIN EN ISO 6385

The ergonomics standard DIN EN ISO 6385 describes the principles set out in DIN EN ISO 26800 in very general terms in greater detail and gives relevant examples. For work systems, DIN EN ISO 6385 remains a fundamental framework from which many other standards on specific topics are derived. This standard establishes principles of ergonomics in the form of elementary guidelines for the design of work systems and defines the essential terms for this purpose. It describes an integrated approach to the design of work systems by interdisciplinary groups with simultaneous balanced consideration of human, social and technical requirements [19].

The goal of an ergonomic design of work systems, and thus also of digital assistance systems, is a reduction of stress, an optimization of strain and an avoidance of impairing as well as a promotion of facilitating effects over the entire life cycle of a work system.

Thus, the formulated occupational science findings aim at a humane and economical design of work systems. The main component of the standard is the definition and explanation of the phases of the design process (Figure 4) [19].

The design process should be of a preventive, participatory nature and include ergonomic design from the beginning with the participation of employees. The process of design includes requirements analysis, analysis and assignment of functions, conceptual design, design of individual elements, realization, implementation and validation, and lastly, continuous evaluation and monitoring of the ergonomic goals set. The criteria of health and well-being, safety, system performance, usability, and cost-benefit provide guidance for evaluation. The authors clarify the necessity of quantitative recording and interpretation of the criteria for continuous improvement and further development of the work systems in operational practice [19].

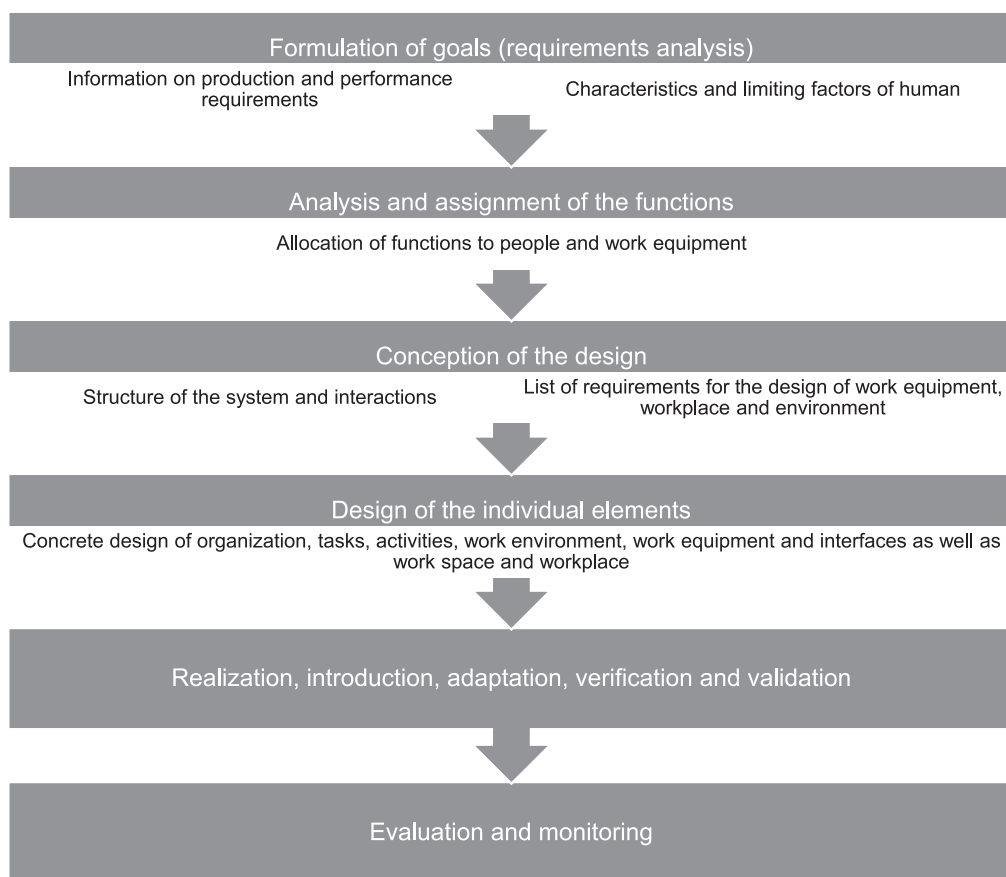


Figure 4. Process of designing a work system according to DIN EN ISO 6385 (DIN EN ISO 6385)

Further information from the professional societies and association supplements the standards listed in this article with practical examples (including VBG – Verwaltungs-Berufsgenossenschaft, DGUV – Deutsche Gesetzliche Unfallversicherung, BAuA – Bundesanstalt für Arbeitsschutz und Arbeitsmedizin).

The fact that the current working world is dominated by digital assistance systems with visual displays is sometimes expressed in the orientation of the DIN EN ISO 9241 series of standards. For visual output devices, however, it is mostly assumed that there are both permanently installed screens and certain fixed inch sizes with a low variability in size. But especially smartphones, tablets, VR (Virtual Reality)- und AR (Augmented Reality) – glasses have significantly smaller display sizes and compared to stationary screens the viewing distance during use is smaller. With regard to the interaction between assistance systems and the user, we are experiencing rapid change due to the rapidly increasing technical possibilities. Existing standards would have to take these current changes into account in a timely manner and should be constantly updated [5].

Furthermore, there are still companies and institutions without systematic and holistic attention to ergonomic principles. Consequently, raising the awareness of the various target groups in the companies, first and foremost the managers and experts, and supporting them in their operational efforts is an essential challenge for ergonomics standardization [3].

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Conclusion

The general concerns of the listed standards are to minimize stresses and strains for the individual user, to expand existing capabilities, and to enable additional capabilities and skills (expanding the scope of action). While at the same time considering technical and economic effectiveness and efficiency [9].

Serviceable systems can offer some benefits. E.g., increased productivity, increased user well-being, stress reduction or avoidance, increased accessibility, and mitigation of the risk of mental and physical stress and strain [10].

In addition to the standards listed in this article, further details, including specific instructions for the use of dialog techniques, which include, for example, dialog by means of menus, command languages and direct manipulation as well as screen forms (standard series DIN EN ISO 9241 – 14 to 16), may be relevant for the individual design solution.

Not only AR and VR represent new technologies to be considered in future standards, but also exoskeletons, which are already beginning their entry into commercial workplaces. In both cases, the legal regulations have not kept pace with the rapid technological developments in all respects. These existing deficits must be addressed [20].

Auditory, tactile, haptic and combined assistance technologies will be increasingly used in the future. The same requirements for usability, dialog design and the design process apply to these. An explanation of the series of standards and practical information for such systems, their development and damage-free use can be helpful [5].

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Автори заявляють, що конфлікту інтересів немає.

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ПОТОЧНІ СТАНДАРТИ ЕРГОНОМІЧНОГО ДИЗАЙНУ ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ ВІЗУАЛЬНИХ ЦИФРОВИХ СИСТЕМ ПІДТРИМКИ В НІМЕЧЧИНІ

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Мета дослідження – враховуючи промислові зміни за часів Work 4.0, необхідно впроваджувати нові цифрові рішення. Систематичний огляд існуючих стандартів має сприяти проектуванню асистивних систем, орієнтованому на людину, і надавати підтримку в розробці та оцінці нових цифрових асистивних систем.

Матеріали та методи дослідження. У рамках спільного проекту «3D-Montageassistent» (фінансується BMBF) проведено пошук у різних базах даних стандартів і посібників з ергономічного дизайну цифрових допоміжних систем, що існують у країні та за кордоном.

Результати. Щодо цілей, то стандарти серії DIN EN ISO 9241 «Ергономіка взаємодії людини та системи», а також DIN EN ISO 26800 «Ергономіка. Загальний підхід, принципи та концепції» та DIN EN ISO 6385 «Ергономіка принципів у проектуванні робочих систем» слід виділити окремо.

Висновки. Багатопрофільне співробітництво формує сучасний шлях медицини праці. Людина перебуває в центрі уваги дизайну й превентивно просувається. Деякі стандарти вже є для орієнтованого на людину проектування систем цифрової допомоги, але розробка нового законодавства не може йти в ногу зі швидкістю розвитку нових технологій. Для нешкідливого використання візуальних цифрових допоміжних систем необхідно усунути недоліки.

Ключові слова: допоміжні системи, ергономіка, стандарти, Work 4.0, зручність використання

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Подяка

Ми хотіли б подякувати Федеральному міністерству освіти та досліджень Німеччини (BMBF) за фінансування науково-дослідного проєкту (FKZ: 03ZZ0441E) альянсу «3Dsensation» у рамках програми «Zwanzig20».

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