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Ergonomics in extended reality: addressing challenges and enhancing user experience

Ľuboslav Dulina, prof. Ing., PhD.
Department of Industrial Engineering, Faculty of Mechanical Engineering,
University of ŽilinaKPI,
Univerzitná 1, 010 26 Žilina.
E-mail: luboslav.dulina@fstroj.uniza.sk, Tel.: +421 41 513 2709

Ján Zuzik, Ing.*
Department of Industrial Engineering, Faculty of Mechanical Engineering,
University of ŽilinaKPI,
Univerzitná 1, 010 26 Žilina.
E-mail: jan.zuzik@fstroj.uniza.sk, Tel.: + 421 41 513 2710

Vladimíra Biňasová, Ing., PhD., DiS.
Department of Industrial Engineering, Faculty of Mechanical Engineering,
University of ŽilinaKPI,
Univerzitná 1, 010 26 Žilina.
E-mail: vladimira.binasova@fstroj.uniza.sk, Tel.: +421 41 513 2727

Beáta Furmannová, Ing., PhD.
Department of Industrial Engineering, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: beata.furmannova@fstroj.uniza.sk, Tel.: +421 41 513 2711

Marián Matys, Ing., PhD.
Department of Industrial Engineering, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: marian.matys@fstroj.uniza.sk, Tel.: + 421 41 513 2740

Abstract: *Extended Reality* (*XR*) technologies, encompassing *Virtual Reality* (*VR*), *Augmented Reality* (*AR*), and *Mixed Reality* (*MR*), are rapidly transforming various industries, offering innovative solutions for training, design, and collaboration. However, the integration of *XR* into work environments introduces new ergonomic challenges that must be addressed to ensure user safety, comfort, and performance. This article explores the role of ergonomics in *XR*, emphasizing the importance of physical, cognitive, and organizational ergonomics. It highlights the need for well-designed *XR* devices to minimize physical strain, the optimization of cognitive load to avoid mental fatigue, and the adaptation of organizational workflows to enhance collaboration in virtual spaces. Additionally, the article discusses the emerging issue of simulator sickness and its impact on *XR* applications. By increasing awareness of these ergonomic considerations, this work aims to contribute to the development of safer and more effective *XR* environments, ultimately enhancing user experience and productivity.

Keywords: industrial engineering, ergonomics, well-being, extended reality

INTRODUCTION

Extended Reality (*XR*) technologies, including *Virtual Reality* (*VR*), *Augmented Reality* (*AR*), and *Mixed Reality* (*MR*), are increasingly used in various fields, including ergonomics. They allow for the simulation of work environments and the evaluation of working conditions without the need for physical devices or prototypes. However, their use is not without challenges - one of the most significant being simulator sickness [1-3].

Simulator sickness is a condition that can cause dizziness, nausea, or disorientation in users while using *XR* devices. These discomforts arise from a mismatch between what the user sees and what their body perceives. This issue can significantly impact user comfort, limit the duration of *XR* usage, and reduce the reliability of results obtained from such simulations [4-6].

The aim of this article is to raise awareness of how simulator sickness affects the use of *XR* technologies in ergonomics. Better understanding this issue is essential to enable more effective utilization of *XR* in the analysis and optimization of working conditions [7-9].

1 CHARASTERISTICS OF EXTENDED REALITY

Extended Reality is a collective term used to describe technologies that blend the physical and digital worlds. It includes *VR*, *AR*, and *MR*, each offering unique ways to interact with and experience digital content. These technologies are rapidly transforming industries by providing immersive and innovative solutions for training, simulation, and design [10, 15].

1.1 Virtual reality

Virtual Reality immerses users in a completely digital environment, replacing their physical surroundings with a computer-generated world. Using *VR* headsets, users can explore virtual spaces, interact with objects, and perform tasks as if they were in the real world. This makes *VR* particularly useful for training, gaming, and simulating complex or dangerous environments [10, 15].

1.2 Augmented reality

Augmented Reality overlays digital elements, such as text, images, or 3*D* models, onto the real world. Unlike *VR*, *AR* does not replace the physical environment but enhances it by adding interactive content. Common examples include mobile applications like *Pokémon GO* or *AR*-assisted navigation systems. In ergonomics, *AR* can be used to visualize design changes directly in a workspace [10, 15].

1.3 Mixed Reality

Mixed Reality goes a step further by allowing digital and physical elements to interact in real-time. For example, a digital object in *MR* can be anchored to a physical table and manipulated as if it were a tangible item. This technology is still evolving but shows promise for collaborative design and real-time problem-solving [10, 15].

The *XR* spectrum encompasses all these technologies, ranging from fully immersive *VR* to minimally augmented *AR*. This continuum demonstrates the flexibility of *XR*, making it applicable across various fields. In ergonomics, *XR* technologies provide powerful tools for analysing and improving workplaces without the constraints of physical prototyping [10, 15].

In Fig. 1 below, a preview of the *XR* spectrum can be seen.

Fig. 1. A preview of the *XR* spectrum [16]

2 CHARACTERISTICS OF ERGONOMICS

Ergonomics is the science of designing and arranging work environments, tools, and tasks to fit the needs and capabilities of people. Its primary goal is to optimize performance, safety, and comfort while reducing the risk of injuries or fatigue. By understanding the interactions between humans and their surroundings, ergonomics helps create systems that enhance productivity and well-being [10, 15].

2.1 Key areas of ergonomics

The following key areas are known in ergonomics [4, 6, 7]:

- *physical ergonomics*,
- *cognitive ergonomics*,
- *organizational ergonomics*.

Physical ergonomics focuses on how the human body physically interacts with tools, tasks, and workspaces, aiming to improve posture, reduce repetitive strain, and prevent *musculoskeletal disorders* (*MSDs*).

Cognitive ergonomics examines mental processes like perception, attention, and decision-making, seeking to design systems that minimize mental workload, enhance focus, and reduce the likelihood of errors.

Organizational ergonomics deals with optimizing workflows, communication, and team structures to improve efficiency, collaboration, and overall workplace dynamics.

The importance of ergonomics is evident in various industries, from manufacturing to healthcare and office work. By designing tools and processes that align with human capabilities, ergonomics not only prevents injuries but also improves efficiency and job satisfaction.

3 RELEVANCE OF XR IN ERGONOMICS

The integration of *XR* into ergonomics allows for simulations that closely replicate real-world conditions. Designers and engineers can evaluate how people interact with their environments, test new tools or layouts, and identify potential risks - all in a safe and controlled setting. However, as promising as *XR* may be, challenges such as simulator sickness need to be addressed to fully unlock its potential [4, 6, 7].

This foundational understanding of *XR* and its spectrum sets the stage for exploring its applications and limitations, particularly in the context of ergonomic assessments and human factors research [4, 6, 7].

4 SIMULATOR SICKNESS

The first *VR* headsets sparked a wave of criticism from users due to the frequent occurrence of motion sickness. Motion sickness occurs when the vestibular sensory input does not align with visual stimuli. This was one of the main reasons for the decline of early virtual reality development. Motion sickness is caused by a mismatch between the signals from the vestibular system and the eyes. The brain then detects this inconsistency and concludes that the body is affected by illness or toxins. As a result, the brain may trigger headaches, nausea, disorientation, or dizziness. Using a *VR* headset can induce a type of motion sickness that doesn't require actual movement, known as simulator sickness [14, 15].

Several methods have been proposed to combat simulator sickness, including unconventional approaches. A study from the *Department of Computer Graphics Technology at Purdue University* suggested adding a *virtual nose* to every *VR* application, which had a stabilizing effect on the user. The company *Virtualis LLC* commercialized this virtual nose under the name *nasum virtualis*. Adding a nose to the user's field of view serves as a fixed reference point to reduce the effects of simulator sickness. The physical nose is within the field of vision, but it is often unnoticed by the person. Most volunteers in studies conducted by *Virtualis LLC* also did not perceive the virtual nose but experienced a 13.5 % reduction in the severity of simulator sickness. Furthermore, they were able to spend longer periods in the virtual world. An example of the *virtual nose* is shown in Fig. 2 [14, 15].

Fig. 2. Demonstration of the *virtual nose* [14, 15]

Another effective method for reducing the effects of simulator sickness is decreasing the response time between the user's actual movements and the *VR* application's reaction. In the real world, there is no latency between the movement of our body and the world around us. Eliminating latency in the virtual world is crucial. An important factor is also the number of *frames per second* (*FPS*) in the application. The higher this number, the smoother the movements and reactions in the virtual world, enhancing the overall experience [14, 15].

CONCLUSIONS

In conclusion, the integration of *XR* technologies into various industries presents both exciting possibilities and new challenges for ergonomics. As *XR* technologies such as *VR*, *AR*, *MR* continue to evolve, it is crucial to apply ergonomic principles to ensure that these immersive environments are not only effective but also safe and comfortable for users.

Physical ergonomics in *XR* must prioritize the design of wearable devices and virtual spaces to prevent discomfort and strain, while cognitive ergonomics must address the mental demands placed on users in complex digital environments. Additionally, organizational ergonomics plays a key role in optimizing how teams interact within *XR* environments, ensuring that these virtual spaces facilitate collaboration without introducing new stressors.

Although *XR* offers numerous benefits in training, design, and productivity, its full potential can only be realized if ergonomic considerations are incorporated into every stage of its development and deployment. As these technologies become more embedded in everyday life, understanding and mitigating issues like simulator sickness and physical fatigue will ensure that *XR* experiences are sustainable and user-friendly. By prioritizing ergonomics, we can harness the power of *XR* while safeguarding user well-being and enhancing overall performance.

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