Extended Realities and the Future of Knowledge Work: Opportunities and Challenges

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Abstract

As extended reality (XR) technologies become more accessible, they have the potential to reshape the workplace, particularly knowledge work. This position paper underscores XR's potential in transforming various aspects of work, including training, communication dynamics, productivity, and performance assessment. It highlights and discusses challenges to successful XR implementation in knowledge work, presenting a balanced perspective on the promising opportunities and ethical responsibilities in integrating XR into the modern workplace.

Keywords: Extended realities, knowledge work, future of work.

Index Terms: J.4 [Computer Applications]: Social and Behavioral Sciences

1 Introduction

Work and technology feed off each other so that the development of one reflects changes in the other and vice versa. Previously, technological development focused on assisting in physical effort and transportation, allowing more extended work periods and expanding geographic reach. It then shifted to automating these physical activities, requiring increased cognitive skills instead of physical ones to operate these devices. Through various examples, we see that technology not only aids work but transforms it. Technology led to changes not only in the work environment but also in how people communicate [1], interact with each other [2], and prepare for work [3]. These cycles of transformation have become increasingly intense and rapid, affecting not only work but also social organizations and human relationships[4].

Although developed in the 1960s by Ivan Sutherland [5], virtual reality (VR) has gained significant investment and adoption, especially in the last decade. Its implementation in knowledge work began as a means to assist in training and task execution, such as pilot training [6] and product design and prototyping [7]. These applications were primarily motivated by VR affordances: the sense of presence (feeling and responding to the virtual experience as if it were real [8]), embodiment (interacting with the virtual environment through body movements [9]), and providing training in a safe yet realistic setting.

Moreover, cost and time reduction played a significant role in VR applications in prototyping, allowing the creation of prototypes in a secure environment with the ability to test different combinations before developing the physical prototype [10]. These implementations required pilots and designers, for instance, to acquire new skills in handling VR equipment and software.

The commercial availability of more affordable standalone VR headsets, an investment that once required thousands of dollars can now be made for less than $500. Similar to how computers in the 1980s transitioned from corporate equipment to personal use [11], [12], extended reality (XR) devices, which encompasses VR, augmented reality (AR) and mixed reality (MR), seem to be following the same path. This change is bringing about a crucial increase in adoption, particularly with recent hardware developments allowing the integration of VR headsets with the physical environment through video passthrough. This advancement facilitates a seamless transition between AR, VR, and MR capabilities within the same headset. While controlled environments were once necessary for VR experiences, it is now possible to use the headset anywhere at any time.

Four decades ago, it would have been challenging to imagine that phones would become personal devices with the same functionality as computers. Today, some might find it challenging to imagine a future in which VR headsets become common as personal devices. However, this is not the viewpoint of the leading companies in the sector, which are investing heavily in XR as the personal devices of the future [13]. How would this change impact knowledge work?

In this context, integrating extended realities, particularly VR, in the workplace represents a transformative shift that enhances traditional work processes and fundamentally redefines how individuals train, communicate, and engage in knowledge work. This paper argues that as XR technologies become more accessible and versatile, they can transform knowledge work by innovating training methodologies, redefining communication dynamics, boosting productivity, facilitating performance assessments, and driving advancements in research and innovation development. While acknowledging challenges, we believe that the widespread adoption of XR in knowledge work is not only likely but also

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meaningful for unlocking unprecedented possibilities in the evolving landscape of knowledge work.

2 EXTENDED REALITIES RESHAPE THE MODERN WORK

Training. The myriad simulation possibilities offered by XR make them an essential tool for training both technical and non-technical skills. In experiences created with computer graphics, where virtual objects can be manipulated and interaction occurs through hand and body movements, literature shows positive gains of VR for tasks requiring repetition and sequence memorization [14], such as equipment handling and safety in construction [15], energy [16], aerospace and pilot training [17], [18], mining [19], automotive [20], and complex medical procedures [21]–[23].

Concerning non-technical skills, such as interpersonal and communication skills, VR can improve performance in job interviews [24] and support development of public speaking skills, both by reducing anxiety [25] and improving public speaking efficacy [26]. Furthermore, it is a promising tool for onboarding teams and fostering a more inclusive work environment by allowing individuals to experience the perspectives of those from different backgrounds, supporting empathy towards others [27].

Especially in situations where emotional processes can influence behavior, such as discussions with divergent opinions or delivering/receiving negative feedback, VR can be a crucial ally in training desired behaviors [28]. For example, rather than learning how to give negative feedback empathetically by practicing the skill with team members, which can cause tensions in the workplace, learners can develop the skill privately and practice repeatedly in VR simulations. In the VR simulations, all interactions can be recorded, supporting learners to review their interactions, analyze their behavior and communication, and improve their skill development through practice and feedback [29]. A study using this approach has shown that practicing difficult conversations in VR affects the user's language style, increasing language markers related to empathy and emotional engagement [30].

Shifting from pre-programmed prompts to artificial intelligence-generated ones facilitates more natural conversations [31], enables a more precise assessment of user performance [32], and allows the delivery of real-time feedback and suggestions for performance improvement [33]. These enhancements not only offer users an experience closer to real-world work scenarios than pre-programmed prompts but also can contribute to more effective soft skills development. With the use of passthrough video, XR could go beyond user-agent interaction and mediate interactions between people, providing feedback and suggestions privately for each user in their headset. The integration of these features can enhance training by providing timely and specific feedback and fostering a more authentic and responsive learning environment. However, much research is needed in terms of skills' language markers, assessment, and feedback efficacy before it is implemented at scale.

XR allows workers to train in a safe, digital environment while triggering emotional reactions similar to what they would experience in the natural environment [34]. It enables more cost-effective and flexible training than traditional role-playing or computer screen simulations. With team members from diverse backgrounds and remote work allowing geographical and cultural expansion, XR will increasingly allow on-demand and personalized training, where employees can develop critical job skills that previously depended on interaction with costly systems, equipment, or specialized individuals, with flexibility in location and time.

Communication. If the future of personal devices involves XR, a significant part of communication between employees and teams may be mediated by this technology. Especially with the development of mixed reality devices, which allow the overlay of digital content onto the physical environment in an immersive way, it will be possible to have meetings with people who are physically in different geographical locations but feeling that everyone is in the same room, experiencing a greater sense of presence than in video conference meetings [35]. While most of these meetings will still be conducted through avatars, the development of low-cost technologies for holographic representations [36], [37] will soon allow individuals to see and interact with the holographic image of people as if they were in the same room. Moreover, as mentioned before, XR technologies coupled with generative AI could mediate people's remote and in-person communication, by assessing the interaction, and providing feedback and suggestions to improve the overall communication.

Self-efficacy. The literature has shown a positive effect of immersion on users' self-efficacy (i.e., the feeling of being able to master a task or knowledge [38]) [14], [39], [40] . This effect has been shown to be mediated by the feeling of agency this technology enables in users by expanding the exploration possibilities. The use of XR both for training in authentic experiences and to support interactions in-person and with the physical world may increase workers' self-efficacy and job performance. In training, XR provides workers the opportunity to develop skills in a controlled and less stressful simulated environment. XR support can provide just in time feedback and support to make workers feel more capable of action. Moreover, because the feedback and suggestions are from a computer and not another person, XR can increase both self-efficacy and performance, as the literature indicates [41]. However, research in that area is still nascent, and more research is needed about feedback specificities and their implications for self-efficacy.

Productivity. The recent integration of productivity applications in VR, such as text editors, spreadsheets, and email [42] is another indication of the transition from a monitor-based digital environment to a headset-based immersive environment. The use of headsets with video passthrough and headphones will allow individuals to control better the visual and auditory stimuli to which they are exposed. For example, the movement of people around someone working in a shared office, which typically causes distraction [43], [44], can be occluded by headset use, leaving only the digital content in the user's field of view. If the user wishes to interact with someone approaching them, they can quickly switch to a passthrough view and see their physical surroundings. Moreover, it is possible to use a 360-degree area for digital work tools. Literature shows that virtual monitors in headsets are a feasible approach in the office for short durations [45], particularly when coupled with assistive methods to reduce head and neck movements [46]. Moreover, a study investigating the effects of using VR for 8h a day during a week indicated a higher task load, and lower flow, system usability, and perceived productivity than a physical work setup [47]. These initial findings indicate the needed for more research on the effects of replacing a monitor for headsets on productivity, fatigue, and social interaction.

Performance assessment. One of the significant challenges in knowledge work relates to formative assessment, i.e, eliciting and using evidence to provide ongoing feedback during the learning process and work execution. Much is invested in research and products to improve the measurement and automation of knowledge work performance. XR devices capture a wealth of data that can help advance those ongoing and frequent assessments. It makes it possible to record activities performed in the virtual environment, users' behavior, body movements, and physiological data such as heart rate and pupil dilation. All these data can be used

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to assist in developing formative assessment metrics for productivity and social and emotional aspects related to work. For example, a study showed that the more people moved while learning concepts in a 360-degree video in-headset, the more confident they felt about learning, but the less they recalled the information received [48]. On the other hand, physical navigation showed positive effects on performance when visualizing data in large displays [49]. Another study demonstrated how pupil dilation can be an indicator of cognitive load in VR [50], which can help create adaptive work environments, allowing adjustment of cognitive load to optimal levels to ensure better productivity and less fatigue. The findings indicate the necessity of carefully selecting the technology and designing the experience according to the task at hand.

Research, prototyping, and testing. The ability to create in 3D with movement and interaction, and even more so, integrate these environments and objects with the physical environment, opens doors to creations previously limited to purely digital 2D environments. Several industries are already using XR to create realistic, digital versions of products and test their physical properties and behavior in various scenarios through digital twins (i.e., a digital replica of a physical environment, object, or materials designed to mirror the real-world counterpart and allow for the synchronization of data and interactions between the virtual and physical entities [51], [52]), as well as plan their logistics and manufacturing [52]. For example, Ford Motors has been using digital twins to incorporate past and present behavior of physical assets and predict their future behavior in order to assist product design before it gets into the assembly line [53]. More than that, in autonomous vehicle testing, it is possible to use XR to understand the behavior of these vehicles in digitally simulated scenarios, reducing risks and costs before the vehicle hits the road [54]. Moving from product development to human behavior, digital twins will significantly advance user experience and consumer behavior research. The recent call from the National Academies [55] for crosscutting programs to support digital twins research among U.S. federal agencies, such as the U.S. Department of Defense, U.S. Department of Energy, National Institutes of Health, and the National Science Foundation, indicates that XR will play a significant role as a tool to simulate natural and artificial environments and advance science, humanities, and industry research.

3 Challenges

Although the landscape of extended reality (XR) usage in knowledge work appears highly promising, it is crucial to be attentive to potential risks that comprehensive and profound implementation may pose. In this section, we discuss particular challenges that should be carefully considered and extensively investigated before XR is widely adopted in knowledge work.

Technical challenges and lack of XR skills. While the adoption of VR headsets has grown substantially in recent years, with millions of headsets being sold annually, most individuals still lack familiarity with XR equipment in the office [56]. Similar to the systematic adoption of computers in the workplace, which required training and dedicated IT departments over years [57], a similar approach is necessary for XR technologies. Financial and personnel resources need to be invested to overcome challenges related to the use of XR technologies, making them effective allies in work and productivity.

Data privacy. The wealth of data collected in XR can be crucial for developing adaptive environments and formative assessment metrics. However, these data can also be utilized for unintended purposes, such as user identification solely through their movements, as demonstrated by Miller et al. [58]. It is essential for companies to establish rigorous protocols for protecting data and for informing employees how the data collected in XR will be used and protected. Companies must adhere to high ethical standards, avoiding unintentional identification, or misuse of employees' non-verbal and physiological data.

Inclusiveness. XR technologies have been developed with little focus on the needs of individuals with disabilities [59], [60]. Most of these technologies exclude individuals with visual or auditory impairments, and few accommodate those with mobility impairments or cognitive divergences [61]. To realize their transformative potential in knowledge work, XR hardware and software need to consider and provide solutions that enable the full utilization of XR by individuals with diverse needs.

4 Conclusion

This paper outlined XR's potential to foster immersive training experiences, improving technical and non-technical skills, communication, and productivity, as well as its significant role in performance assessment by capturing diverse data metrics. As XR technologies become increasingly accessible, the evolving landscape demands ongoing exploration, collaboration, and an understanding of the ethical implications. Hitting this balance will pave the way for XR's responsible and effective integration in knowledge work, boosting performance concurrent with potential benefits for worker psychological well-being, while ensuring a sustainable and inclusive future for the modern workplace.

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