European Agency for Safety and Health at Work

DISCUSSION PAPER

THE FUTURE OF WORKING IN A VIRTUAL ENVIRONMENT AND OCCUPATIONAL SAFETY AND HEALTH

Introduction

Technological developments have led to digitalisation that has transformed workplaces dramatically over the past decades. As a result, many workplaces have either become exclusively virtual or they have evolved into a 'hybrid' model, many work tasks and processes performed virtually and others having physical presence. In this discussion paper we explore the future of working in a virtual environment. A virtual work environment or a 'virtual workplace' is a workplace that exists digitally. It is created and maintained through the Internet and the use of information and communication technologies (ICT). A virtual workplace has also been defined as a network of several workplaces technologically connected (via a private network or the Internet) without regard to geographic boundaries (Raghuram et al., 2019).

Individual virtual workplaces vary in how they apply existing technology to facilitate team cooperation, and various definitions of virtual work exist in the literature accordingly. These include the following:

- *Telecommuting* or *Teleworking* or *Remote work*: the availability and use of communications technologies, such as the Internet, to work in an offsite location.
- *Online jobs*: jobs that are being done only online, virtually. In Europe, the term 'e-worker (or e-nomad)' is generally used to refer to all work that is carried out virtually.
- *Hot desking*: employees do not have individual desks but are rather allocated each day to a desk where they can access technology services, including the Internet, email and computer network files.
- *'At-home' jobs*: jobs done at home, also known as home-based jobs, are typically done 100 % of the time from a home office without required trips to another workspace.
- *Virtual team*: employees collaborate by working closely together and in regular contact using ICT-enabled technologies (ICT-ETs), although physically located in different parts of the world.
- *Distributed team/Dispersed virtual team*: groups of people who work (often from home) across geographic boundaries and time zones.

Although there have been earlier projections of an increase in virtual work, the Covid-19 pandemic has accelerated this development with a large part of the working population now working remotely and virtually from home most or all of the time. It is projected that this new reality will continue post-pandemic, bringing with it new opportunities and challenges (Smit et al., 2020).

Looking more into the future, working virtually will involve increased work in a *virtual reality (VR)* and *augmented reality (AR)* environment: VR is defined as 'a wide variety of computer-based applications commonly associated with immersive, highly visual, 3D characteristics that allow the participant to look about and navigate within a seemingly real or physical world" (Lioce et al., 2020, p. 50).

Box 1. VR, AR and XR

Virtual reality (VR) is generally defined based on the type of technology being used, such as head-mounted displays, stereoscopic capability, input devices, and the number of sensory systems stimulated'' (Lioce et al., 2020, p. 56). Also relevant to this type of work is augmented reality (AR), a type of VR that overlays digital computer-generated information on objects or places in the real world for the purpose of enhancing the user experience (Milgram & Kishino, 1994). Extended reality (XR) represents the spectrum between the part-digital world of AR and the fully immersive experience of VR. It is sometimes also referred to as spatial computing or immersive technology (PwC, 2019).

In addition to *definitional* issues on working in a virtual environment, it is important to also consider *contextual issues* of virtual work. As mentioned, digitalisation is inherently linked to virtual work since it covers a broad spectrum of ICT-ETs, for example, ICT tools, robotics, artificial intelligence (AI), VR, AR, the Internet of Things (IoT), wearables and Big Data (EU-OSHA, 2018).

However, the spread and prevalence of the application of ICT-ETs are currently varied across Europe and across different sectors and socio-economic groups. This presents future challenges in terms of sustainability, employment and training, among others. Furthermore, workers in virtual work environments are often atypical and platform economy workers, and may be working under non-standard employment arrangements (OECD, 2019). A large proportion of these workers may be affected by job and income insecurity, increased competition as online the labour market becomes increasingly global, and lack of social protection. Atypical work increases in times of economic crisis, such as the current one associated with the Covid-19 pandemic. These contextual issues are important in considering the prevalence and future developments of working in virtual environments.

Prevalence of working in a virtual environment

Regarding the prevalence, information is available on Teleworking or Remote work only, which is likely to be the largest part of virtual work. In 2019, 14.4 % of employed persons in the EU, aged 15-64, usually or sometimes worked remotely –virtually- from home (Eurostat, 2020) with self-employed workers accounting for the majority. The situation varied widely across EU Member States, with the Netherlands and Finland reporting 14.1 % of employed people usually working from home in contrast to 0.5 % in Bulgaria, 0.8 % in Romania and 1.9 % in Greece.

Differences in remote working have been noted especially between countries with larger shares of employment in ICT-intensive sectors and others (Eurofound, 2020). ICT-intensive sectors as well as engineering, manufacturing and healthcare have also seen a move towards the use of VR and AR in the workplace (PwC, 2019). A 2019 PwC report predicted that nearly 23.5 million jobs worldwide will be using AR and VR by 2030 for training, work meetings or to provide better customer service. According to the same report, VR and AR have the potential to add 1.6 trillion US dollar to the global economy by 2030.

On the one hand, these numbers seem to show that VR and AR may have significant impact in the future, as a form of virtual work, both on the types of existing jobs and on new jobs with implications for health, safety and well-being. On the other hand, however, in a worldwide workforce of 3 billion workers, the number of 23.5 million jobs is not that high (less than 1 %). Regarding their use, the PwC report states that, based on the focus of investments, AR and VR will mostly serve the function of product and services development, testing and training, as well as enhanced communication and collaboration methods (PwC, 2019).

The Covid-19 pandemic drastically changed working practices, with the proportion of Europeans working remotely virtually shooting up from 14 % to 40 % (Eurofound, 2020). According to experts, this is unlikely to return to pre-pandemic levels (e.g., Barrero, Bloom, & Davis, 2021). For example, since lockdowns have eased, office capacity has been reduced by 30 % to 50 % in some cases (Ceurstemont, 2020).

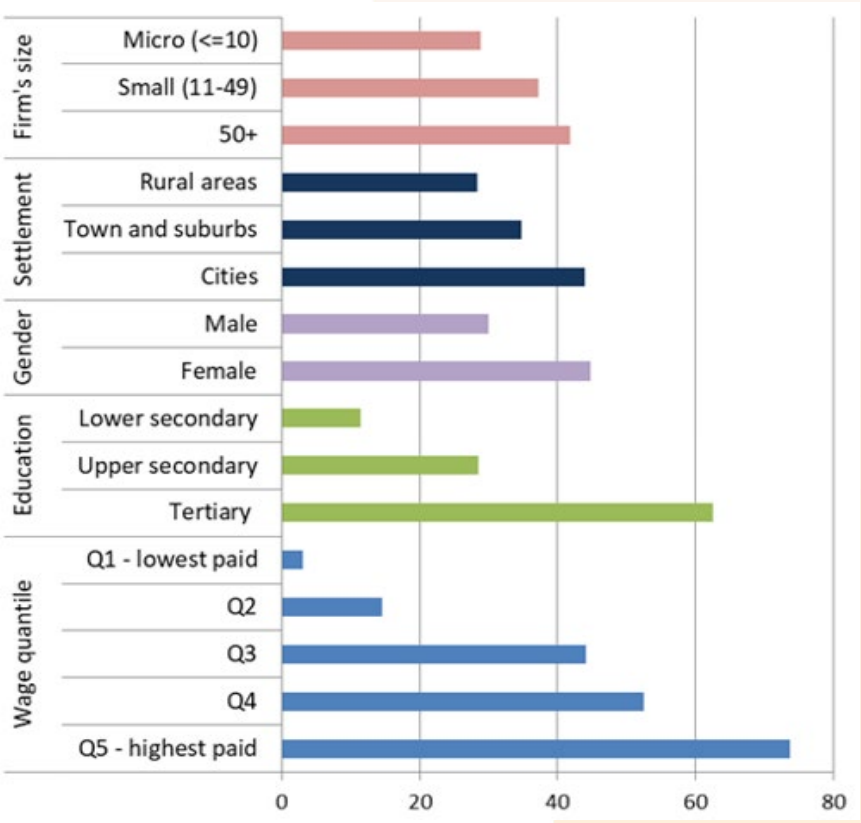
Countries in northern Europe such as Denmark, Finland and Sweden, where remote working was more common due to job availability in sectors conducive to virtual telework, have seen the biggest proportion of workers begin to telework virtually during the pandemic. However, apart from job availability, cultural differences have been reported to be at play since many workplaces in southern Europe are still set up in a more traditional way, including more traditional management practices.

In the context of remote working arrangements, trust is particularly important since it is harder for the employer to monitor production at distance. On the other hand, employees working remotely might feel they are socially ‘unseen’ and left out of work communication flows and networks. Indeed, more remote work has been found to take place in countries with a high trust index such as the Nordic countries, the Netherlands and Denmark (Eurostat, 2018 as cited in Citi GPS, 2020). Furthermore, more virtual teleworking has been prevalent among highly skilled workers, where the highest rates were found among ICT professionals, managers and teachers (Milasi et al., 2020a).

In order to project *future developments* post the Covid-19 pandemic and beyond, it is important to understand the current scale of possible virtual teleworking across Europe. The fraction of teleworkable employment has been estimated to range from 35 % to 41 % in two-thirds of EU countries, with the highest value in Luxembourg (54 %) and the lowest in Romania (27 %) (Milasi et al., 2020a). The highest share of teleworkable employment appears to be in the Nordic (Denmark, Finland, Iceland, Norway, Sweden) and Benelux (Belgium, the Netherlands, Luxembourg) countries with the lowest shares in eastern Europe and southern Europe. Furthermore, the socio-economic profile of workers in teleworkable occupations shows stark differences, with 74 % of workers in the top 20 % highest paying jobs being able to telework, versus only 3 % of workers in the 20 % lowest paying jobs (Milasi et al., 2020b). A divide can also be seen in terms of educational qualifications, with around 66% of tertiary education graduates working in teleworkable occupations, against a much smaller share of those with lower qualifications (Milasi et al., 2020b).

Further differences emerge in relation to gender, with a much higher share of women than men (45 % compared to 30 %) in teleworkable occupations, reflecting patterns of sectoral segregation. This is due to the fact that women are under-represented in sectors such as agriculture, mining, manufacturing, utilities and construction with limited teleworkability and are more likely to be represented in office-based, secretarial or administrative jobs that are more open to remote virtual working (Milasi et al., 2020a). Teleworkable employment also tends to be more common among native-born workers than foreign-born and among larger rather than smaller establishments. At the same time, more than 40 % of employees living in cities are in teleworkable occupations, against fewer than 30 % of those living in rural areas, which reflects the fact that cities have a larger fraction of employment in knowledge- and ICT-intensive occupations (Milasi et al., 2020a, see Figure 1).

Figure 1. Employees in teleworkable occupations by workers' characteristics, EU-27 (%)



Source: Adapted from Milasi, Bisello, Hurley, Sostero & Fernández-Macías (2020)

Future trends and developments

- **Future projections of virtual telework across EU countries, sectors and organisations**

The important role of virtual telework in preserving jobs and production in the context of the Covid-19 crisis has been highlighted by the European Commission in its communication on the 2020 country-specific recommendations (European Commission, 2020). Once the pandemic ends, remote virtual work is likely to continue since teleworking can cut costs and improve business efficiency (Ceurstemont, 2020).

However, although the fraction of remote teleworkable employment in Europe is between 35 % and 41 %, this estimation, according to Eurofound (2020), likely provides an 'upper bound' on the percentage of jobs that can currently be done remotely in an efficient way. First, the majority of teleworkable jobs requires extensive social interaction but widely used videoconference systems and lack of widespread use of high-speed networks cannot currently match the quality of face-to-face interactions, and especially in sectors such as medicine and education, although this is rapidly changing. On this basis, Milasi et al. (2020a) estimate that only 13 % of employment in Europe is in teleworkable occupations that involve no or limited social tasks and can in principle be carried out remotely with no or limited loss of quality. Second, lack of experience with digital tools and remote working arrangements may limit the uptake and effectiveness of virtual teleworking. A recent EU report (Sostero et al., 2020), for example, found that one-third of the EU labour force has very limited digital skills or none at all. In order to avoid a divide between countries, and between highly educated white-collar workers in higher-wage jobs and lower-educated, blue-collar workers in lower-wage jobs, access to remote virtual working arrangements should be provided to all together with extensive training opportunities (Milasi et al., 2020a). However, less than 25 % of enterprises in the EU-27 provided ICT training to their staff in 2019, ranging from 37 % in Finland to 6 % in Romania (Milasi et al., 2020b).

In terms of sectors, a report by the European Agency for Safety and Health at Work (EU-OSHA (2018), projected that the sectors with the largest potential rates of job losses in the future due to digitalisation are manufacturing, distributive trades[1], and administration and support services. The areas with the greatest potential for growth in jobs are professional, scientific and technical activities, information and communications, and repair of computers and household goods. A report by the Organisation for Economic Co-operation and Development (OECD, 2019) agrees with the projected growth in ICT- and knowledge-intensive sectors. According to more recent Eurofound (2020) projections post-pandemic, nearly all financial services employment is potentially virtually teleworkable (93 %), as is 79 % in information/communication, and around two-thirds in real estate, professional, scientific and technical activities, education and public administration. Service sectors with projected lower shares of teleworkable employment include health (30 %), retail (27 %) and accommodation/food services (16 %), while the primary sector, manufacturing and construction all have low shares of teleworkable employment at 10-20 %. Estimations by EU-OSHA (2018), OECD (2019) and Eurofound (2020) point out that knowledge-intensive and professional sectors are expected to see most of their activity taking place virtually.

Furthermore, post-pandemic, the adoption of telework could be more difficult in countries and sectors where small firms account for larger shares of employment, due to their limited use of technology and less use of virtual telework (Eurofound, 2020). Larger companies are typically more likely to adopt virtual telework than smaller ones. Countries such as the Netherlands, Finland and Sweden, where firms with 50+ employees accounted for a larger share of total employment in knowledge-intensive business services, showed before and since the pandemic a larger share of teleworkers in that sector than countries like Italy and Croatia, where medium-large firms employed less than 15 % of workers in that sector (Eurofound, 2020).

The projected impact of technological developments

Developments in technology will allow more advanced virtual communication processes such as 5G livestreaming, enhanced document sharing and collaborative revision, and videoconferencing supported by telerobotics and/or with 3D effects. The following changes in communication and collaboration processes are expected to be developed over time (Citi GPS, 2020):

- In-person meetings > online meetings, real-time chat, automated transcription.
- Project whiteboards > collaborative work management and workstream collaboration.
- File servers, document versioning > online/cloud storage.
- Manually recolouring an illustration > AI-driven colour optimisation in digital illustration.
- E-mail and spreadsheets business process tracking > no-code applications to automate the business process.
- Manually data collecting analysis > end user analytics software.

Instead of shared calendars and fileservers, 'groupware' collaboration offerings like SharePoint are now being replaced by on-demand sharing of software concepts, like SaaS (for Software as a Service), cloud compute/synchronisation, and machine learning, as further innovations in communication and collaboration technologies (Citi GPS, 2020).

[1] Distributive trade is defined as the totality of all forms of trade activities, from the procurement of goods from the manufacturer to delivery of these goods to the consumers. It includes wholesale and intermediation trade, retail and trade in motor vehicles and motorcycles. Distributive trade is known as the chain of distribution.

Within these developments, VR and AR have the potential to transform virtual work dramatically by changing and facilitating it. As soon as faster processors and high-speed networks such as 5G technology become widely available, VR will enable geographically diverse workplaces to connect and unify. For example, high-tech conference technologies like telepresence robots and hologram technology will allow workers a superior experience in virtual meetings. Furthermore, they may increase tele-migration, the possibility of transferring project work or project tasks or even more permanent work tasks using advanced digital applications to anywhere in the world.

Box 2. Telepresence robots

A **telepresence robot** is a computer, tablet or smartphone-controlled robot that includes a video camera, screen, speakers and microphones so that people interacting with the robot can view and hear its operator and the operator can simultaneously view what the robot is 'looking' at and 'hearing' (Paulos & Canny, 2001).
Telepresence robots include features such as click-to-drive, obstacle avoidance, zoom video, and even mixed reality overlays where virtual 3D objects are added into the video stream to appear as if they are in the real world. All these features contribute to an informative and fully immersive remote experience during navigation.

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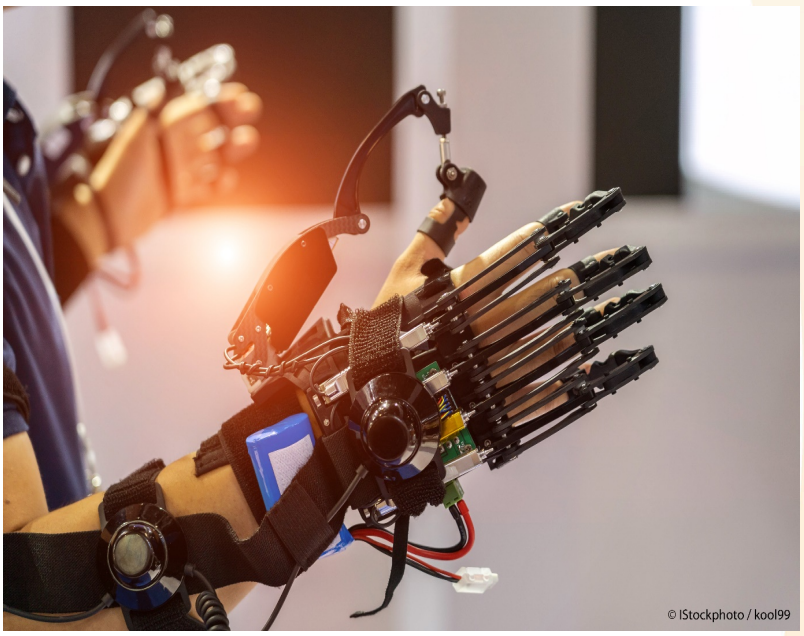
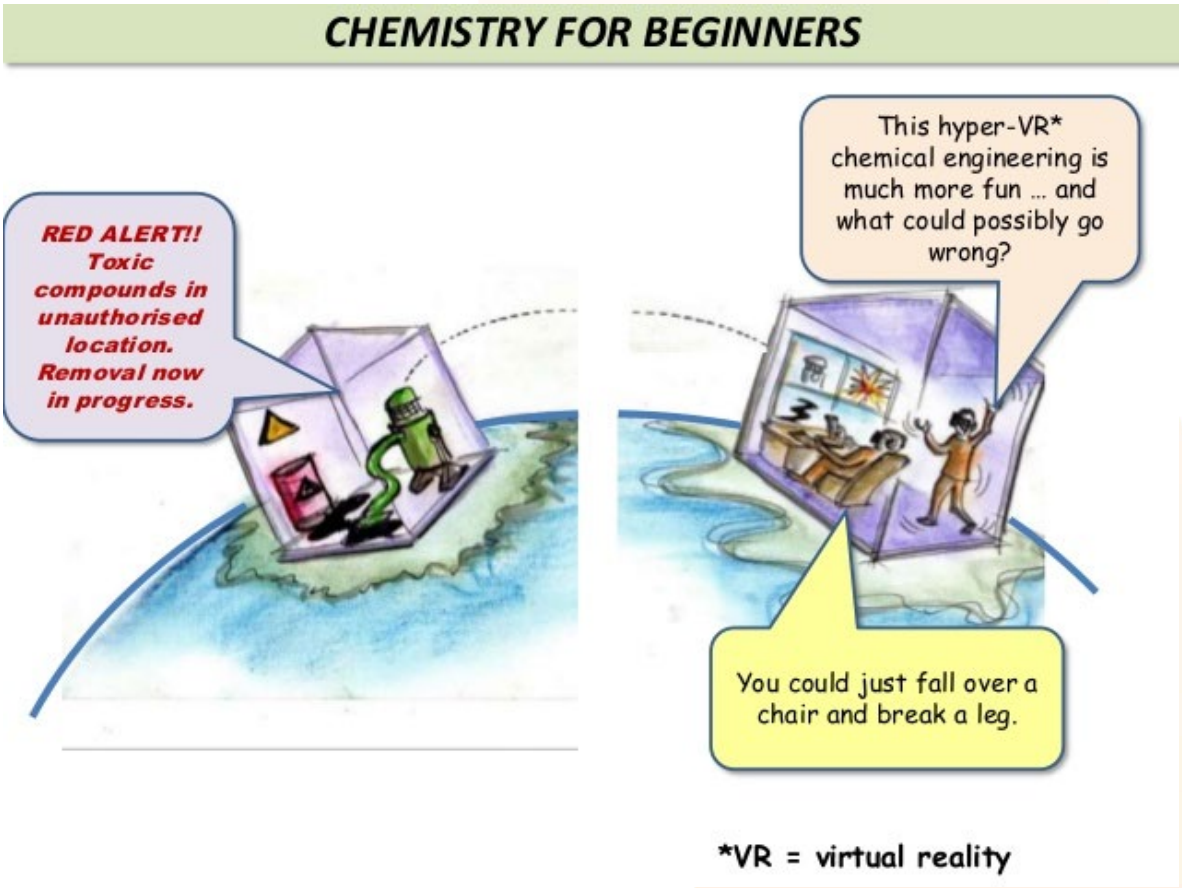


Developments in *haptics*, the use of technology that stimulates the senses of touch and motion, especially to reproduce in remote operation or computer simulation the sensations that would be felt by a user interacting directly with physical objects, will offer advanced sensory stimulation. Haptics has the potential to enhance user interfaces with gestural controls in workstations, which could add an extra dimension to data visualisation. This can be applied in healthcare, engineering, automotive and other industries to help users interact with digital interfaces in a more seamless way, and it is expected to facilitate a better work experience, better communication and teamwork, and enhanced productivity (PwC, 2019). Facebook/Metari is already working on VR chatrooms VR headsets for business purposes.

VR and AR can also be used to organise documents and other resources in our *peripheral vision* for easy reference or retrieval, and display real-time changes to critical data as we work on projects (EU-OSHA, 2018).

Additionally, VR and AR provide the opportunity for enhanced (and safe) training and testing environments. They are already improving training resources and techniques for surgeons, astronauts and automotive manufacturers by allowing to build new prototypes and test new methods and knowledge. Organisations like NASA are already using VR to develop and test new processes and products faster and safer. The same technology could be used by a number of other industries, for example, healthcare and manufacturing. In this way, it will allow organisations operating in various countries with different national standards to ensure that their products are compliant with these (Citi GPS, 2020).

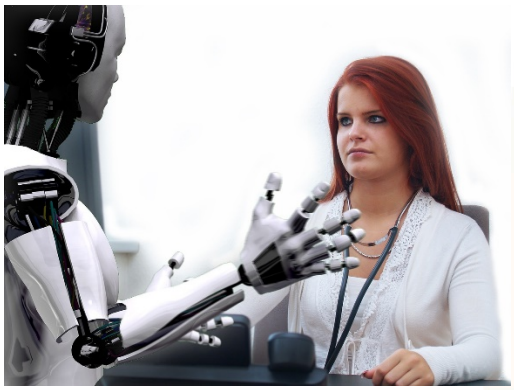


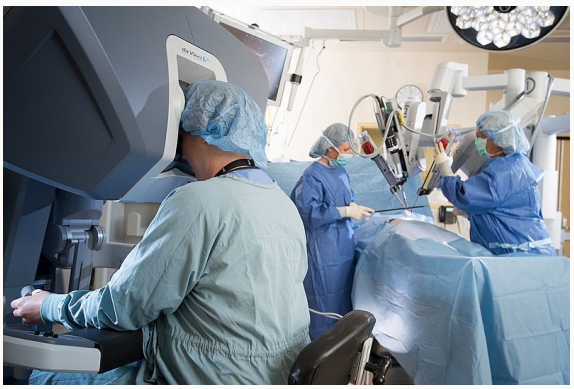
Source: Adapted from EU-OSHA (2018)

In customer service, VR can be used for trouble shooting as well as to train employees how to serve customers better, faster and more efficiently and therefore with lower costs (PwC, 2019).

In maintenance, technicians can be taught best practices with a VR video, instead of having to attend in-person training. Even more radically, companies could translate actions in VR to a robotic counterpart in the workplace. This would eliminate the requirement to go to work since problems could be fixed remotely, through smart devices, allowing robots to carry out manual tasks and communicate with network users (EU-OSHA, 2018).

Similar transformative changes will take place in other sectors such as healthcare where virtual prototyping will accelerate product design and testing and the use of telepresence robots and VR can advance personalised telemedicine diagnosis and treatment (see Box 3).





Box 3. Healthcare in the future

VR and AR are expected to have a **transformative impact on the healthcare sector** in terms of both frontline patient care and also training. VR is already being used to give medical students greater access to operating theatres. It is also being used to enable doctors based in different locations to collaborate remotely, discuss upcoming surgical procedures and execute them. Operating theatres and realistic scenarios in VR help train doctors and surgeons and test their decision-making and responses to stressful situations in a risk-free environment. AR glasses can overlay scans and X-rays onto a patient's body, augmenting the view a surgeon has. AR can also help a doctor gain access to a patient's test results and data at their bedside, rather than logging them on a computer or checking paper notes. VR may also be used therapeutically, for example, creating applications to help people cope with anxiety. The physician's role in the future will focus more on communication and interpersonal relationships with patients and their families, which could take place through telepresence robots, and less on determination of treatment decisions.

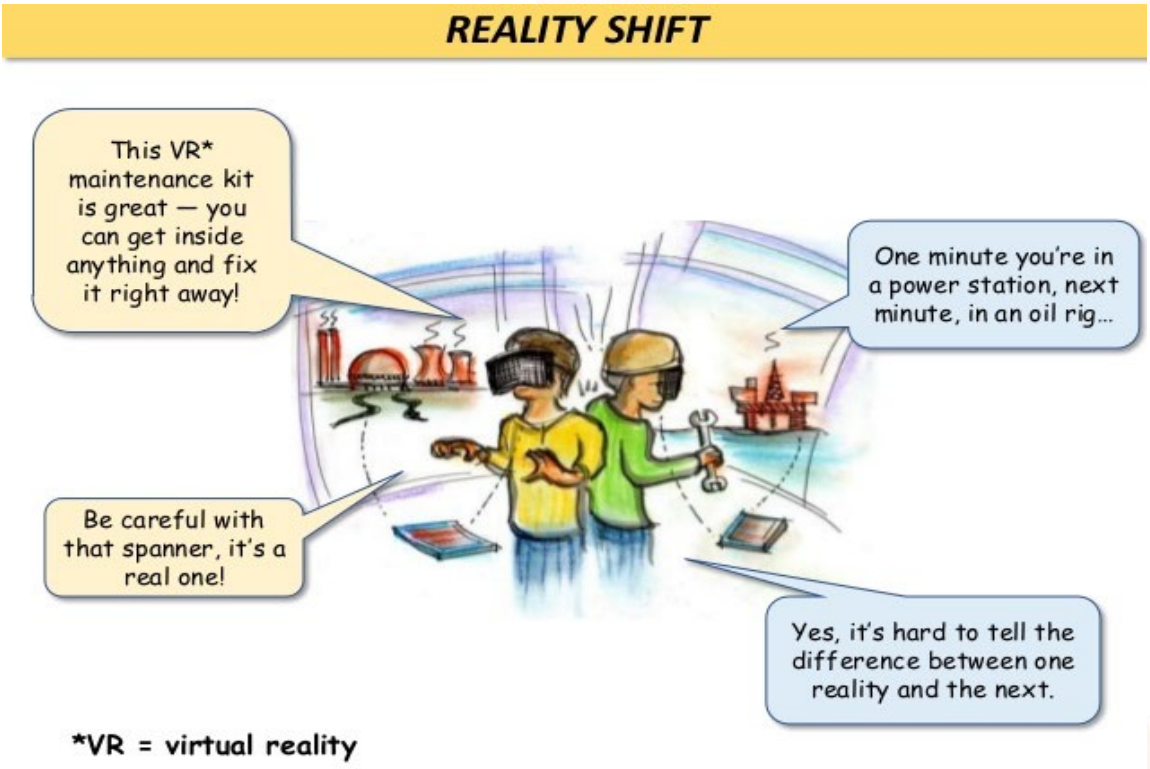
Talent acquisition is another emerging application for VR in the workplace since it can allow prospective employees to virtually experience in a deeply immersive way the workplaces and environments their new job requires in order to make a fully informed decision about pursuing that particular position or field of work. Additionally, VR will allow employers to evaluate their candidates' skill sets, to establish where they excel and where they might need further guidance or training (PwC, 2019).

Challenges and opportunities for OSH

This section focuses on OSH issues in relation to working in a virtual environment, taking into account the information presented in the previous sections of this article. Working in a virtual environment will continue to accelerate following the Covid-19 pandemic. However, the pace of progress will vary across countries and sectors and will depend on actions taken at policy, research and practice levels.

Since working in a virtual environment is a complex area that involves various aspects (e.g. virtual telework, working virtually from home, working in a VR/AR environment), there are a range of occupational safety and health (OSH) considerations associated with it, entailing both risks/challenges and opportunities and associated dilemmas (summarised in Table 1, below).

In terms of *opportunities*, virtual work and the use of VR can have many advantages. Virtual work can be conducted remotely, while VR can further facilitate work from anywhere, connect individual workplaces, and make work faster, more efficient and more cost-effective (PwC, 2019). This way, commuting and carbon emissions will be minimised, contributing to more leisure time and a better work-life balance as well as a greener environment. Communication and collaboration processes can be improved (utilising telepresence and in the case of VR and AR utilising advanced sensory stimulation making the communication process much more realistic) and multidisciplinary work and teamwork strengthened (PwC, 2019). Virtual work can make jobs more flexible and more accessible to a larger and more diverse pool of people, including older, younger and migrant workers. This may result in longer working lives.

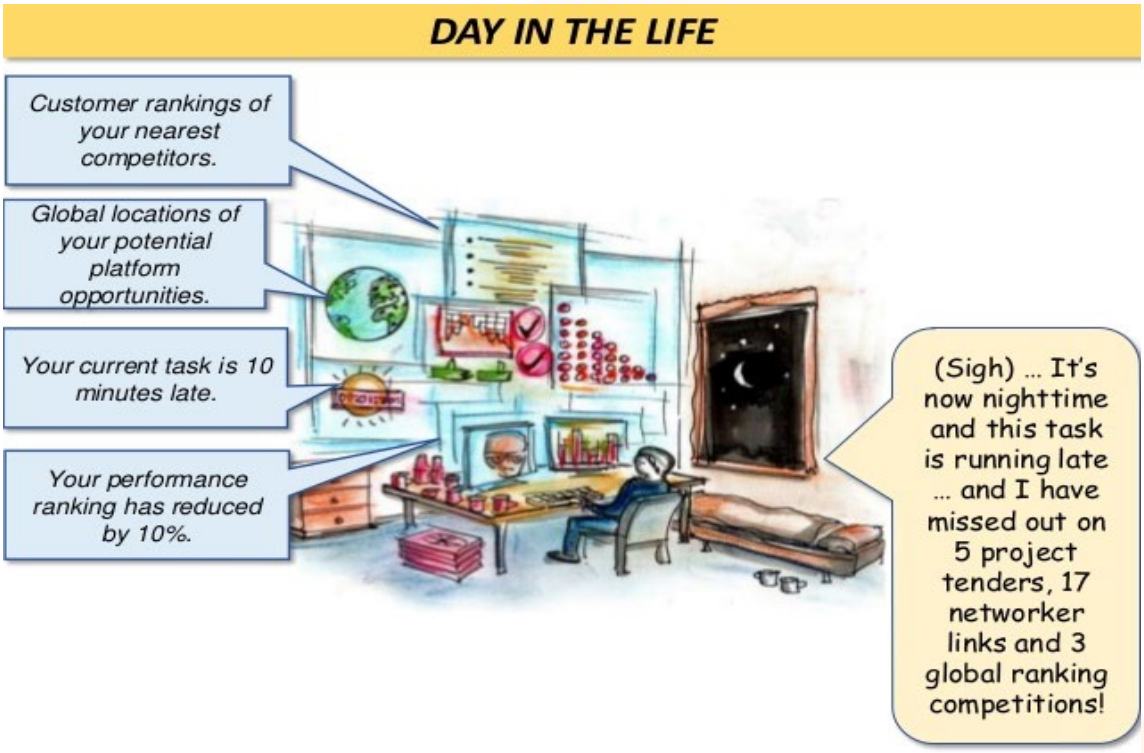


Source: Adapted from EU-OSHA (2018)

VR and AR can remove humans from hazardous environments, reducing for example physical risks, ergonomic risks, biological risks and exposure to dangerous substances. They can create safe, controlled and well-equipped testing and training environments (Citi GPS, 2020). Virtual prototyping will safely test (and develop faster) new products, methods and knowledge. The use of smart devices can also provide preventative information to enable more effective monitoring of work processes and prevention by design. This can also be enabled by communicating and working with robots through VR interfaces and avatars (Citi GPS, 2020). There are also opportunities in rethinking risk assessment and management processes, using Big Data, smart devices and so on, and encouraging more active participation of workers in these processes (EU-OSHA, 2018). AR can incorporate instructions, which could reduce human error, as workers would not need to refer to separate guidance while their hands are needed for maintenance activity. AR can also improve situational awareness by providing supplementary contextual information, for example on the presence of hidden hazards such as asbestos, electricity cables and gas pipelines (EU-OSHA, 2018).

Digitalised management methods and VR can enable more accurate hiring of staff, data processing, distribution of work, performance monitoring and appraisals as well as tracking wellness aspects (PwC, 2019). This has the potential of facilitating less hierarchical, more participative management practices and could lead to new collective bargaining models (Smit et al., 2020). It can also support the development of healthy workplaces. VR and AR in particular can help with worker relaxation through immersing them in a relaxing VR environment.

However, for many of the above OSH opportunities there is a flip side and **an associated OSH risk or challenge**. With the ability to work virtually from anywhere, and many workers doing so from home, the boundaries between work and private life may become blurred. As a result, workers may work longer hours and have difficulty disengaging from work, feeling physically and emotionally exhausted, especially where there is lack of experience of virtual work and lack of support (ILO, 2020). Many workers may exhibit online addiction (wanting to always be ”on”). The use of performance-enhancing drugs might increase, especially in the case of addiction, longer working hours and strict performance monitoring (EU-OSHA, 2018).



Source: Adapted from EU-OSHA (2018)

Psychosocial risks and work-related stress will increase since the pace of work will be faster and employees might have less control over their work (ILO, 2020), especially if this is machine-dictated. Changes in technology will bring about frequent changes in work processes, job insecurity will increase and there may be more frequent job changes. Additionally, remote virtual work from home may increase feelings of isolation and loneliness (ILO, 2020). Lack of social interaction and support might emerge as challenges despite technological advancements supporting better communication. Challenges in communication might also arise from the use of telerobots and avatars. More diverse workforce participation might make communication more challenging while cyberbullying may increase in virtual work (EU-OSHA, 2018), especially since more workers will work in virtual teams, often having little opportunity to get to know their fellow workers who might be living in other countries or might be hired only to complete that particular task or project. These issues may result in a rise in mental ill health problems such as anxiety and depression (ILO, 2020).

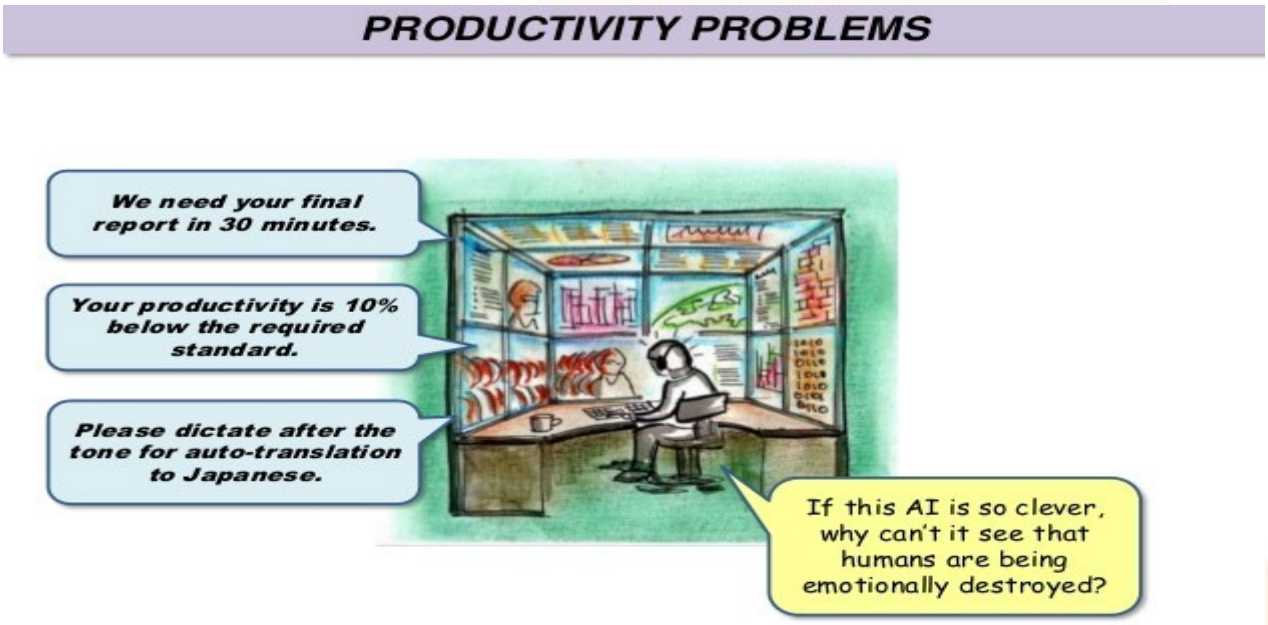
Furthermore, workers with caretaking responsibilities might face additional burden without appropriate support since, as seen during the pandemic, remote working from home has often had to be juggled with additional care responsibilities due to school closures and looking after older relatives (Milasi et al., 2020b).

Working from home has implications in terms of suitability of workstations, equipment and connectivity and could pose ergonomic risks, leading to musculoskeletal disorder (MSD) problems. Sedentary work is common in virtual work and can lead to obesity, heart disease, diabetes and MSD problems. I

The use of new smart equipment and devices, especially in the case of VR headsets and other devices, can present challenges in terms of eye strain, repetitive strain injury, increased cognitive load and decreased situational awareness. As a result, there can be issues such as loss of awareness of users' actual surroundings during and even for some time after their use, physical disorientation and motion sickness that can result in accidents (EU-OSHA, 2018). Cybersickness, which refers to a constellation of unpleasant physiological symptoms, such as nausea and dizziness, experienced as result of exposure to a virtual environment is expected to become more prevalent with the increased use of VR headsets (Yildirim, 2020). Cybersickness has been found to be associated with 'presence', the observer's sense of psychologically leaving their real location and feeling as if transported to a virtual environment (Weech et al., 2019). AR devices overlay reality with computer-generated information that could make it less easy to see OSH-critical situational information because of distraction, disorientation or information overload (EU-OSHA, 2018). Other rarer issues associated with VR include increased photosensitive seizure risk and epilepsy. In the case of interacting with robots (e.g. telepresence robots) through VR interfaces and avatars, more cognitive load and technostress are possible,

especially if the robot controls the pace of work and outpaces the worker (Paulos & Canny, 2001). Headset design will need to take accessibility and diversity into account to ensure devices are appropriate for various users (Citi GPS, 2020).

The introduction of faster data processing, algorithmic management and audible command technologies means that the pace of work will become faster and workers might have less control and autonomy over their work (Wood, 2021). The algorithmic management of work and workers, AI, monitoring technologies, such as wearables, together with IoT and Big Data may lead to cybersecurity (which is also related to the use of social media) and data protection issues, ethical issues and information inequality with regard to OSH (EU-OSHA, 2018; Moore, 2019).



Source: Adapted from EU-OSHA (2018)

Virtual working may lead to an increase in atypical work and non-standard employment and increasing numbers of workers treated as self-employed independent workers, falling outside existing OSH regulation and social protection provisions (OECD, 2019). As a result, there can be job insecurity and frequent job changes among the workforce. ICT- and knowledge-based work sectors will continue to see increasing virtual work (Citi GPS, 2020).

Some sectors, like advertising, will be completely transformed with many job losses. The same will be true in sectors like healthcare with more developments in telemedicine and e-health. While sectors like manufacturing will see a decrease in jobs, more investment in VR will bring about new highly specialised jobs (Citi GPS, 2020). This will imply a need for upskilling and reskilling of the workforce. Success with this will define the future of (virtual) work in Europe and a decrease in the divide between countries and workers in terms of job content, education and pay. SMEs will be able to invest more in new technology and virtual work if they are provided with appropriate support (OECD, 2019).

Challenges to prevention and management of OSH risks, regulation and policy development in relation to working in a virtual environment

Challenges to the prevention and management of OSH risks in relation to working in a virtual environment stem from the dilemmas outlined in Table 1. One of the key challenges is keeping pace with developments. Technological advances take place rapidly and as a result new working conditions emerge together with new and emerging risks. Research and policy often lag behind changes in practice. Lack of knowledge on newly emerging OSH challenges complicates policy-making and inspection. A key consideration is responsibility of employers and workers as well as social protection given the rise of the independent worker. At the same time, it is necessary for regulation not to hinder technological progress and negatively affect competitiveness. Virtual work and new technology also present opportunities both for worker collective representation and bargaining and for inspection. Throughout this landscape, issues in relation to privacy, security and ethics should be carefully considered.

Table 1. OSH dilemmas in relation to working in a virtual environment

Responsibility	How to define employer and worker responsibility in relation to risk management while working in new virtual work contexts and conditions (e.g. remote virtual work; virtual work from home; working in a VR environment). How can social protection be ensured even for independent workers?
Policy	How to achieve a good balance between regulation and other types of policy in order to address new and emerging risks in virtual work while not hindering rapid progress. How can inspections be more agile?
Autonomy and control	How to balance flexibility through virtual work with worker autonomy and control over their work. How can worker participation and collective bargaining be supported?
Privacy	How to protect worker privacy in a virtual environment while using algorithmic monitoring and surveillance. How can ethical hiring, appraisal and evaluation processes be developed maintaining human dignity?
Technology interface	How to incorporate new technological interfaces (e.g. enhanced sensory stimulation, robotics) in virtual work processes while ensuring human-sensitive and human-in-control design. How can SME infrastructure and worker skills be developed appropriately?
Productivity	How to balance organisational economic performance against social performance. How can health, safety and well-being be addressed in a preventative way in the context of virtual work? How can an economy of well-being perspective be promoted and adopted?
Workforce diversity	How to support more participation of diverse groups (e.g. female, older, younger, migrant, low-educated workers) in virtual work while developing their skills and providing appropriate support. How can a lifelong perspective to the development of the workforce be promoted?

Additionally, lack of knowledge and skills is a broader challenge since, as discussed earlier, one-third of the EU labour force has very limited digital skills or none at all. If the accelerated move towards more virtual work is considered, also in light of Covid-19, there is a very high risk of the existing divide in terms of virtual work becoming wider and resulting in wider inequalities. As discussed, this divide concerns both EU countries and groups of workers, with the Nordic and Benelux countries being better versed in virtual work and southern and eastern EU countries lagging behind. Similarly, blue-collar, lower-educated and paid workers are at a disadvantage in comparison to white-collar workers in higher-paid jobs with tertiary education qualifications.

There are also issues in relation to accessibility to virtual work for older and migrant workers who can participate in the workforce more and for longer with appropriate support through re- and upskilling. Participation in the workforce can also be enhanced through virtual work, provided there is support and a cultural shift so that there is balance between work and other responsibilities. Lack of knowledge and infrastructure in relation to virtual work is also a challenge in micro-enterprises and SMEs that do not prioritise OSH adequately. Support and engagement of smaller enterprises remains a big priority.

Implications for policy

There is a need for the policy framework to be re-examined in light of new and emerging risks and a good balance to be found between hard and soft law, with an important role for social partners. Existing regulation would need to be updated regularly to cover and address new and emerging risks. The regulatory framework should clarify OSH liabilities and responsibilities in relation to new systems and new ways of working (ILO, 2019). Considering the complicated landscape of virtual work, other forms of policy, such as standards and voluntary social partner agreements, can play an important role. A good example is the recent framework agreement on digitalisation (2020)[2]. Given the differences across sectors in terms of virtual work, sectoral approaches would hold great potential. Holistic policy models would need to be developed adopting a lifelong

[2] See: https://ec.europa.eu/social/main.jsp?langId=en&catId=329&furtherNews=yes&newsId=9729 or find the pdf here: Final_22_06 20_Agreement on Digitalisation 2020.pdf

perspective to working life with a strong well-being focus. Ethical issues need to be strongly considered and addressed. The development of codes of conduct could prove helpful in doing so (EU-OSHA, 2018).

Policy efforts should aim to minimise the EU country divide in terms of digital skills and virtual work and should be accompanied by appropriate support and infrastructure development programmes. These should continue to place a great focus on micro-enterprises and SMEs. Workers should be involved in the implementation of proposed strategies.

Virtual work presents opportunities both for worker collective representation and bargaining and for inspection. Inspection can be improved using Big Data and smart devices (EU-OSHA, 2018). Even though trade union membership is expected to decline, ICT-ETs can facilitate the development of new, more direct collective bargaining structures (OECD, 2019). Finally, the provision of effective OSH services to virtual workers would need to be considered through the use of new technology.

Implications for research

Since there is rapid technological development, it is important for new knowledge to be generated fast. Therefore, the research infrastructure needs to be enhanced through EU research funding mechanisms, including Horizon Europe. OSH observatory and forecasting capabilities should also be strengthened in order for relevant data to be generated fast. New technologies can be utilised to this end. Collaboration between researchers, professional associations, industry, social partners and governments in research and innovation in developments of ICT-ETs is of upmost importance and should take into account human aspects. A strong 'prevention through design' approach should be taken that integrates a user/worker-centred design approach (EU-OSHA, 2018).

Research should address new and emerging risks, for example, risks associated with VR and AR as well as psychosocial risks in virtual work. A strong focus on well-being and adopting and supporting a lifelong perspective to working lives should be prioritised. Research should also address emerging ethical issues and strongly consider ethical dimensions of data generation and management.

Implications for practice

With developments in ICT-ETs, there are opportunities to rethink risk assessment and management processes, using Big Data, smart devices and so on (EU-OSHA, 2018). There are already practical applications in these areas that need to be coordinated in order to develop ethical practices. Therefore, the aforementioned partnerships and collaboration among stakeholders are important.

OSH training is a key area that will be transformed through the use of VR and AR. Practitioner and worker skills will need to be updated accordingly in relation to working in a virtual environment. Furthermore, professional associations have an important role to play in relation to the development of ethical codes of practice for their members. Finally, international and national standards can be defined to promote good practices in working in a virtual environment.

References

Barrero, J.M., Bloom, N. & Davis, S.J. (2021) Why working from home will stick. Centre for Economic Performance Discussion Paper No. 1790. London: London School of Economics. https://cep.lse.ac.uk/pubs/download/dp1790.pdf

Ceurstemont, S. (2020, September 1). Teleworking is here to stay – Here's what it means for the future of work. *Horizon Magazine*. Available at: https://ec.europa.eu/research-and-innovation/en/horizon-magazine/teleworking-here-stay-heres-what-it-means-future-work

Citi GPS (2020). *Technology at work v5.0: A new world of remote work*. Citigroup. Available at: https://ir.citi.com/td2TMf%2FvvpzNPqaucEszMhDfq%2Fq%2ByImXWvzH61WVNip7Ecd1v7edrIrz6nCHdxkoR2AmAYyMDa4%3D

EU-OSHA (European Agency for Safety and Health at Work) (2018). *Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025*. European Risk Observatory report. Publications Office of the European Union, Luxembourg. Available at: https://osha.europa.eu/en/publications/foresight-new-and-emerging-occupational-safety-and-health-risks-associated

Eurofound (2020). *Living, working and COVID-19*. COVID-19 series. Publications Office of the European Union, Luxembourg. Available at: https://www.eurofound.europa.eu/publications/report/2020/living-working-and-covid-19

European Commission (2020). *2020 European Semester: Country specific recommendations / Commission recommendations*. Available at: https://ec.europa.eu/info/publications/2020-european-semester-country-specific-recommendations-commission-recommendations_en

Eurostat (2020). *How usual is it to work from home?* Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200424-1#:~:text=In%202019%2C%205.4%25%20of%20employed,2009%20to%209.0%25%20in%202019

ILO (International Labour Organisation) (2019). *Work for a brighter future. Global Commission on the Future of Work*. Available at: https://www.ilo.org/global/publications/books/WCMS_662410/lang--en/index.htm

ILO (International Labour Organisation) (2020). *Managing work-related psychosocial risks during the COVID-19 pandemic*. Available at: https://www.ilo.org/global/topics/safety-and-health-at-work/resources-library/publications/WCMS_748638/lang--en/index.htm

Lopreiato, J.O., Downing, D., Gammon, W., Lioce, L., Sittner, B., Slot, V., Spain, A.E., & the Terminology & Concepts Working Group (2016). *Healthcare simulation dictionary*. Available at: http://www.ssih.org/dictionary

Milasi, S., Bisello, M., Hurley, J., Sostero, M., & Fernández-Macías, E. (2020a, August 14). *The potential for teleworking in Europe and the risk of a new digital divide*. VoxEU. Available at: https://voxeu.org/article/potential-teleworking-europe-and-risk-new-digital-divide

Milasi, S., González-Vázquez, I., & Fernandez-Macias, E. (2020b). *Telework in the EU before and after the COVID-19: Where we were, where we head to*. Joint Research Centre Science for Policy Brief, JRC120945. Available at: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc120945_policy_brief_-_covid_and_telework_final.pdf

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems, E77-D*(12), 1321–1329. Available at:https://search.ieice.org/bin/summary.php?id=e77-d_12_1321&category=D&year=1994&lang=E&abst=

Moore, P.V. (2019). *OSH and the future of work: Benefits and risks of artificial intelligence tools in workplaces*. EU-OSHA Discussion Paper. Available at: https://osha.europa.eu/en/publications/osh-and-future-work-benefits-and-risks-artificial-intelligence-tools-workplaces/view

OECD (Organisation for Economic Co-operation and Development) (2019). *Going digital: Shaping policies, improving lives*. Paris: OECD Publishing. Available at: https://doi.org/10.1787/9789264312012-en

Paulos, E., & Canny, J. (2001). Social tele-embodiment: Understanding presence. *Autonomous Robots*, *11*, 87–95. https://doi.org/10.1023/A:1011264330469

PwC (2019). *Seeing is believing*. Available at: https://www.pwc.com/gx/en/industries/technology/publications/economic-impact-of-vr-ar.html

Raghuram, S., Hill, N.S., Gibbs, J.L., & Maruping, L.M. (2019, January 16). Virtual work: Bridging research clusters. *Annals*, *13*(1), 308–341. https://doi.org/10.5465/annals.2017.0020

Smit, S., Tacke, T., Lund, S., Manyika, J., & Thiel, L. (2020, June 10). *The future of work in Europe: Automation, workforce transitions, and the shifting geography of employment*. McKinsey Global Institute. Available at: https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-in-europe

Sostero, M., Milasi, S., Hurley, J., Fernández-Macías, E., & Bisello, M. (2020). *Teleworkability and the COVID-19 crisis: A new digital divide?* Joint Research Centre Technical Report, JRC121193. Seville: European Commission. Available at: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/teleworkability-and-covid-19-crisis-new-digital-divide

Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: A review. *Frontiers in Psychology*, *10*, Article 158. https://doi.org/10.3389/fpsyg.2019.00158

Wood, J. (2021). Algorithmic management: Consequences for work organisation and working conditions. JRC Working papers 2021/07. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/algorithmic-management-consequences-work-organisation-and-working-conditions

Yildirim, C. (2020). Don't make me sick: Investigating the incidence of cybersickness in commercial virtual reality headsets. *Virtual Reality*, *24*, 231–239. https://doi.org/10.1007/s10055-019-00401-0

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This discussion paper was commissioned by the European Agency for Safety and Health at Work (EU-OSHA). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect the views of EU-OSHA.