Telepresence and simulators – modern use of Virtual Reality in robotics and training with possible application of AI

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Example of technologies under development in Virtual Reality Laboratory

- VR training simulators eg. for:
  - Firefighters
  - Underground miners

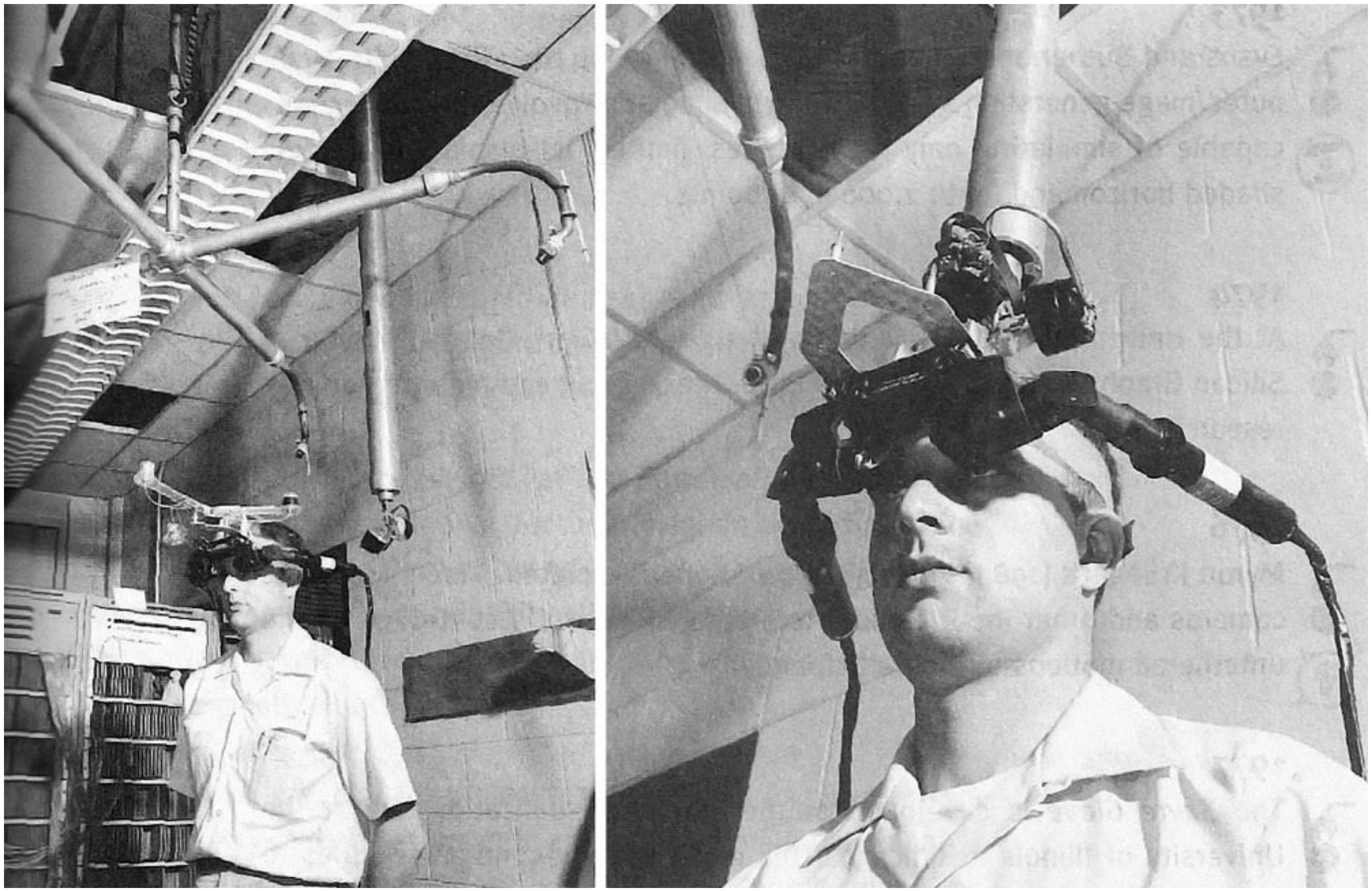
- Vehicle and industrial machinery simulators

- Mobile robots with arms
- Exoskeletons to reduce musculoskeletal loads

What is the Virtual Reality?

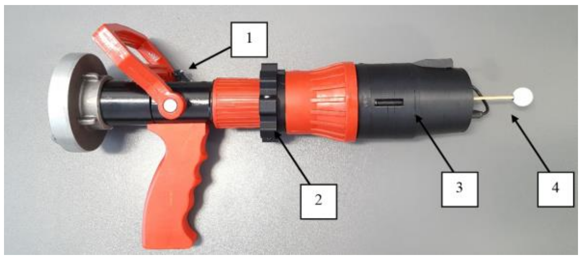
Using Human-Computer Interface typical for VR, the impression of being in another place (telepresence) is created.

Virtual Reality
- more than half a century earlier

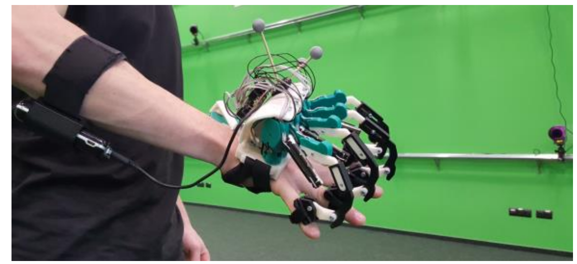


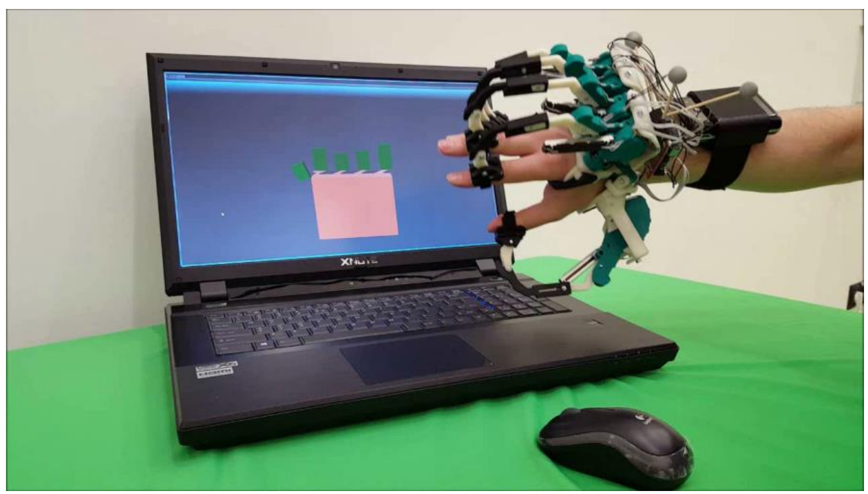
Damokles Sword, 1968 r.

Examples of components of human-computer interface used in VR



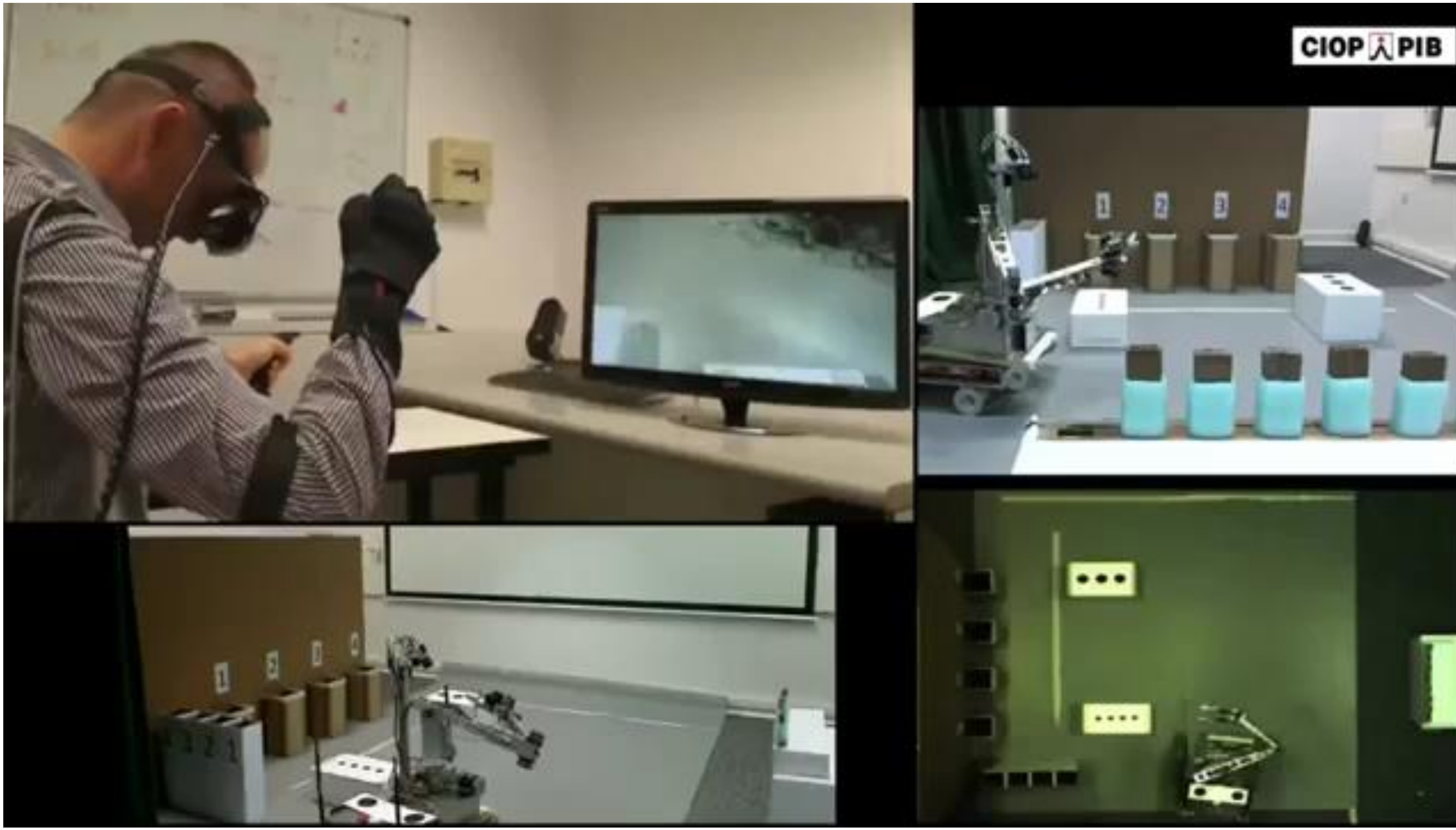
nozzle


glove with force feedback



Some of possible practical applications of VR

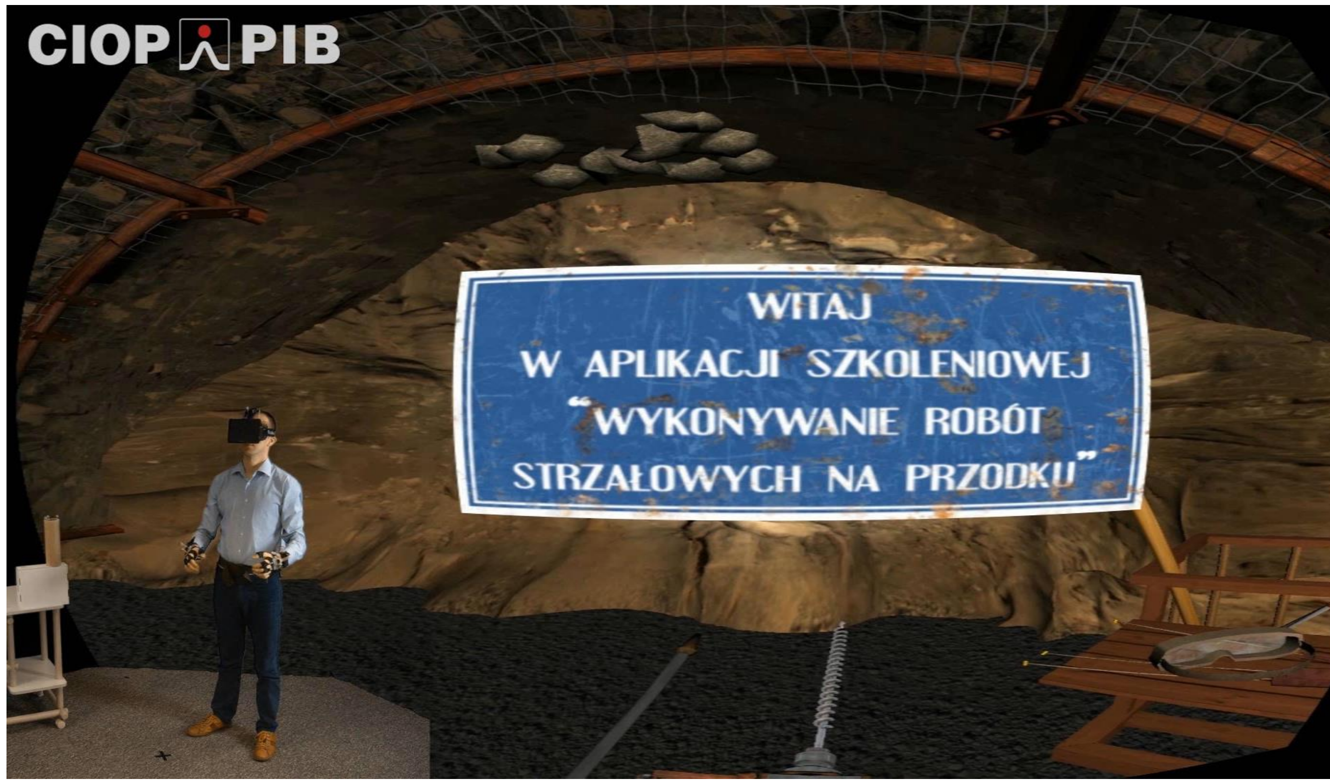
Telepresence and teleoperation



Application of VR systems for safety training

The use of high immersive virtual reality systems enables:

- achieving a high degree of realism of the simulation
- simulation of various scenarios under controlled conditions
- facilitate the memorization of information and consolidate skills using realistic, interactive simulations



Example of virtual reality training introduced to practice

Benefits resulting from the use of virtual reality techniques to support training

- acceleration of the training process,
- reduction of training costs,
- increasing the effectiveness of training,
- making the form of the training more attractive,
- engaging muscle memory to improve developing the skill of working safely and efficiently
- enabling the transfer of „tacit knowledge" (knowledge based on experience)

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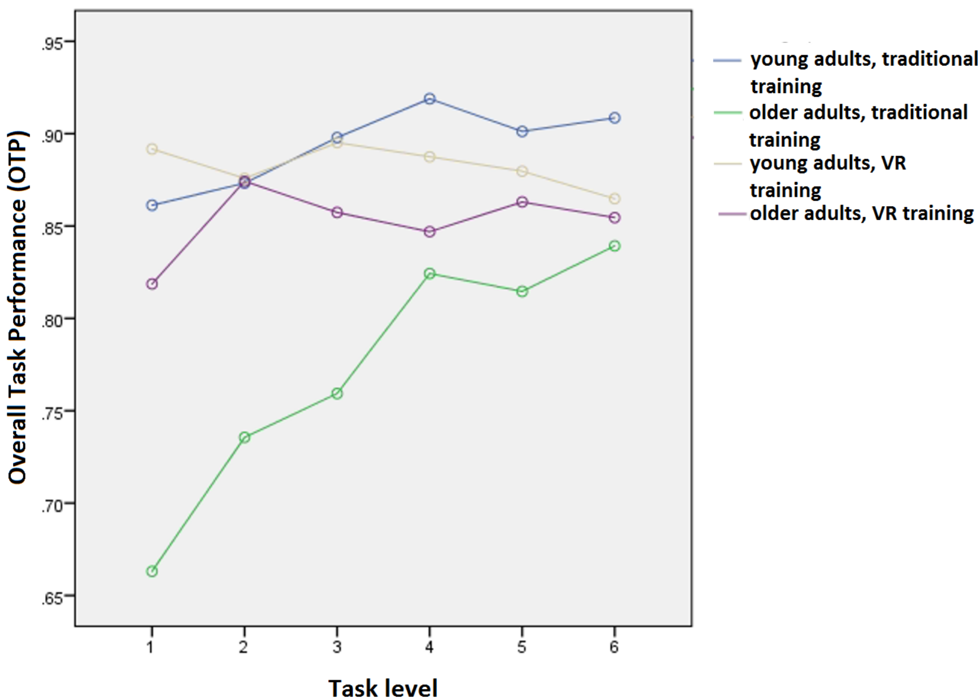
VR-based team training is possible also

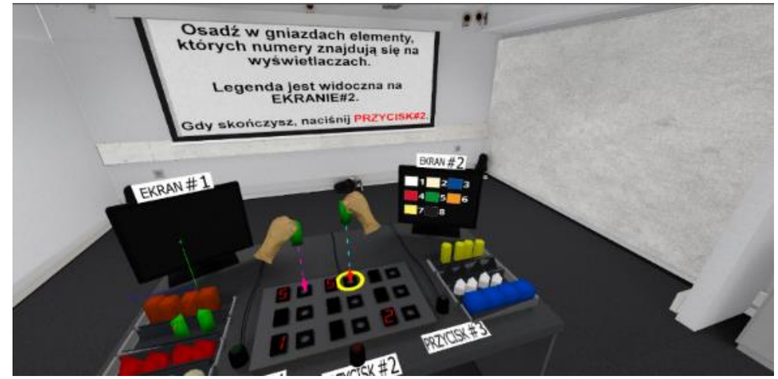
Cognitive skills

A group of elderly (55+) who participated in traditional training performed a manual task with less correctness than other volunteers.

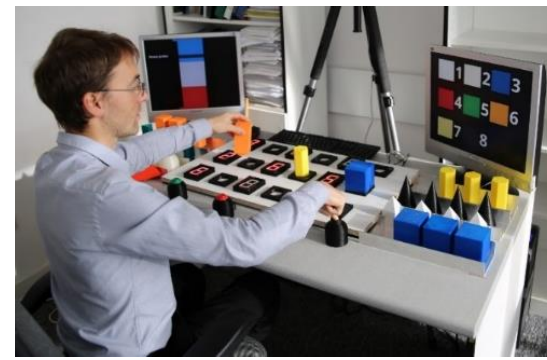
The group of elderly who participated in VR training did not significantly differ in the correctness of task performance from both groups of young people.

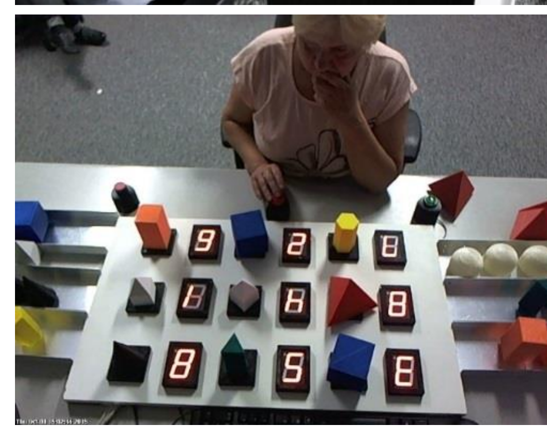


120 volunteers participated in the study.



An image observed by a person in a virtual environment





Simplified workplace simulator

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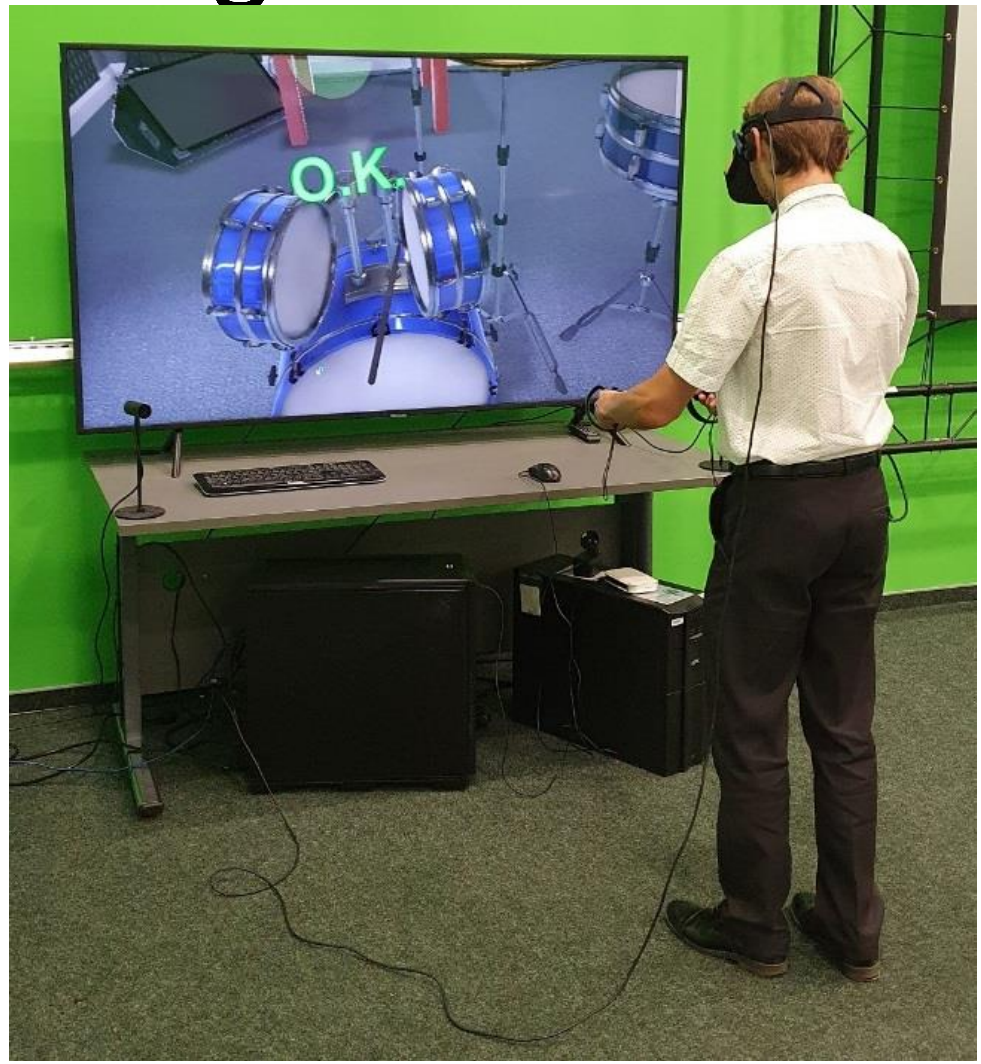
Rehabilitation games

Example of training game (Knight) with a TV-based interface

Rehabilitation games



Example of training games (Library and Drummer) with a VR-based interface (Oculus Rift S)

Telepresence and teleoperation

Telepresence, teleoperation and VR training for operators

The two-arms robot developed at CIOP-PIB remotely controlled by the operator using VR equipment like Head Mounted Display (HMD). Images from the stereo-camera mounted on the robot are displayed in HMD. Robot's arms are following the operator's hands movement. The operator can use a glove with force-feedback also.

Virtual reality can be used to simplify the work of teleoperators who remotely control robots. In this way, the robot can perform work in a dangerous, remote area, while the operator remains in a safe area.

VR can be also used for teleoperators training.

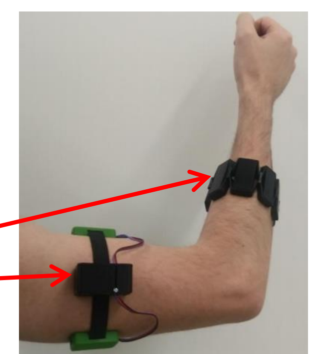
Teleoperation or Exoskeletons?

Exoskeletons can be used to reduce stress on the musculoskeletal system. While passive exoskeletons only facilitate the holding of objects and tools, much more advanced powered exoskeletons allow to increase the strength of the worker.

Powered exoskeleton for upper limbs developed at CIOP-PIB.

The movement of the exoskeleton is controlled by muscle activity signals (EMG) signals from upper limbs.

Detectors of EMG signals



Teleoperation or Exoskeletons?

Teleoperated robots are also an alternative to wearable robots (exoskeletons) to support physical work. Remote control of a two-armed robot has the following advantages over an active exoskeleton:

- Safety: the operator is not threatened by any incorrect operation of the robot, the possibility of the robot falling over or the presence of harmful factors in the robot's workplace.
- Ergonomics: the operator does not have to wear an exoskeleton; therefore, the operator's movement is not hindered by the exoskeleton. Furthermore, the operator can take a break from work at any time without the need for the time-consuming process of exiting and re-entering the exoskeleton.
- Ability to control many mobile robots, switching the operator between different robots (this makes it possible to continue working after a failure using a second robot).
- The cost of building a remote-controlled robot can be many times lower than an exoskeleton-type robot for the whole body.

Teleoperation or Exoskeletons?

Teleoperated robots are also an alternative to wearable robots (exoskeletons) to support physical work. Remote control of a two-armed robot has the following advantages over an active exoskeleton:

- A mobile robot can be much smaller than a human in an exoskeleton because it does not contain elements of the exoskeleton mounted on the operator. Therefore, the robot can move around better in rooms intended for people.
- Energy-saving and efficiency, a longer working time without having to charge the battery: the mobile robot uses less energy than a full body exoskeleton because it does not have to support the operator's body (e.g., it is easier to prepare arms with lower weight).
- Possible easy adaptation to the terrain in which the robot should move through the use of various mobile platforms: wheeled platform, tracked platform, two-legged, multi-legged (e.g., hexapod).

Teleoperation or Exoskeletons?

It should be noted that teleoperated robots also have some drawbacks. When compared to exoskeletons, the following weakness can be enumerated:

- Delays: probably the greatest weakness of teleoperated systems. There are delays in sending data from robot to operator (e.g., image from cameras), delays in sending orders from operator to robot and delays in executing orders. These delays can make the work challenging and slow it down compared to using exoskeletons.
- Signal propagation: sending a large amount of data with low delays is not possible without a telecommunication infrastructure. Therefore, the use of teleoperated robots is limited to places with such an infrastructure. Please note that owing to difficulties with wireless communication, some teleoperated robots are wired. Exoskeletons can be used without access to a telecommunication system.
- Space requirements: two work stations are needed. The first for the robot and the second for the robot's operator.

The influence of human-machine interface, VR training and operator age on execetued tasks is investigated

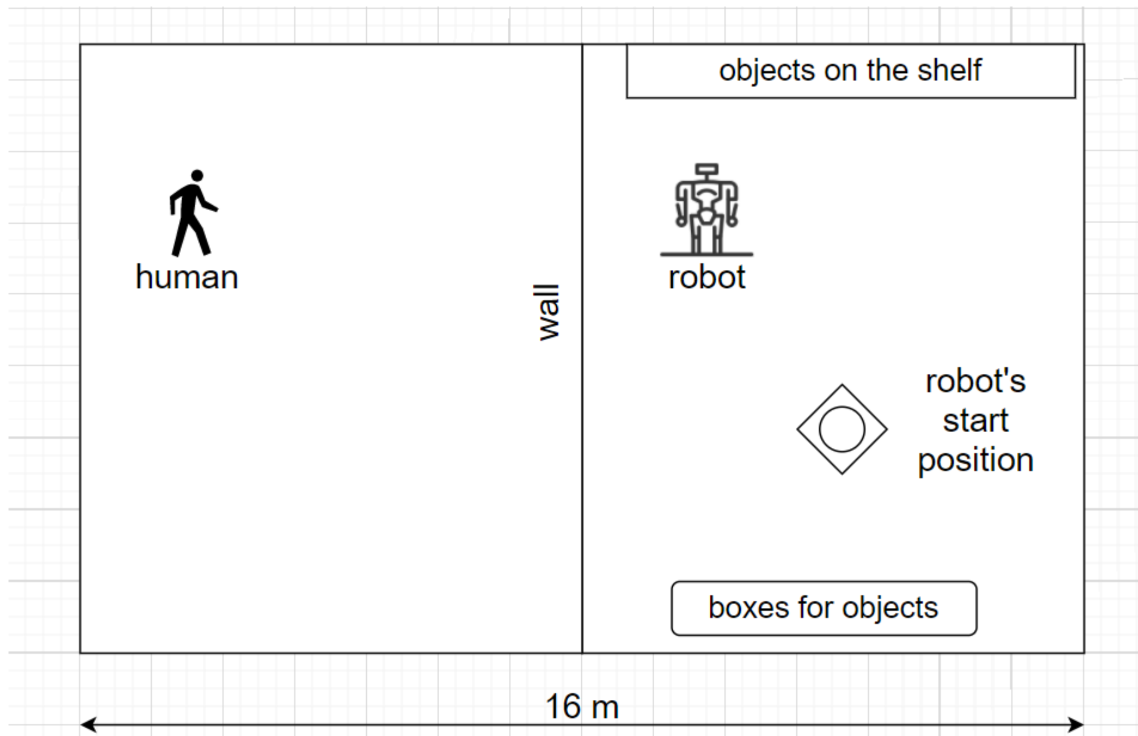
75 subjects were divided into five following groups:

1. **YS** – Young, Sitting: Young adults (below 30 years old), controlling the robot in a static position
2. **YSVR** – Young, Sitting, VR training: Young adults after VR training
3. **YW** – Young, Walking: Young adults, controlling the robot by walking
4. **YWVR** – Young, Walking, VR training: Young adults after VR training
5. **ESVR** – Elderly, Sitting, VR training: Elder adults (people over 50)

In each trial, the subject's task was to move the robot towards one of five objects, capture the object, and then move the robot towards the container and drop the object so that it falls inside.

The experiment

Robot carrying one of the elements (in the left gripper). On the left behind the robot is a white wall separating the robot from the area where the subject can move. Objects that should be carried are visible on the shelf on the right side of the image. The laboratory diagram is shown below.



The robot

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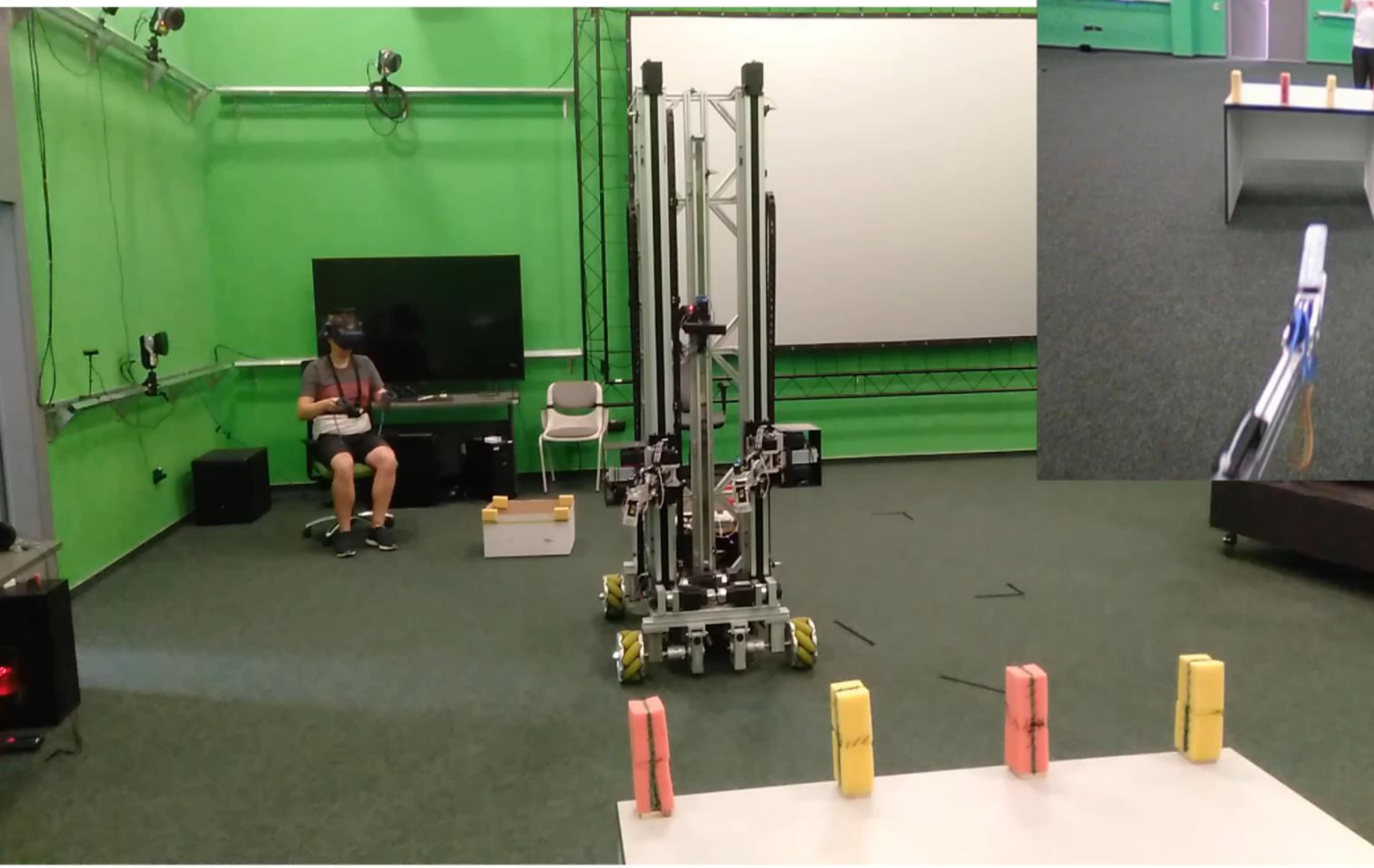
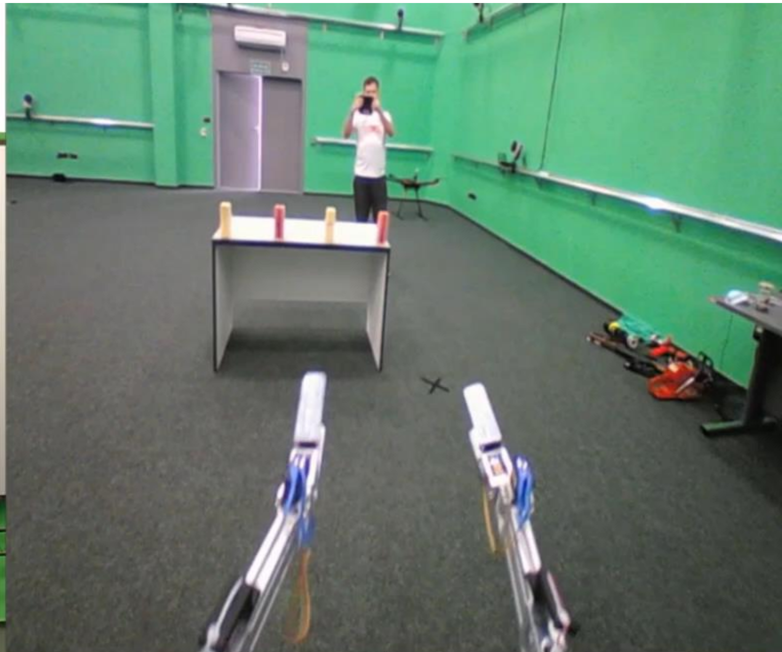
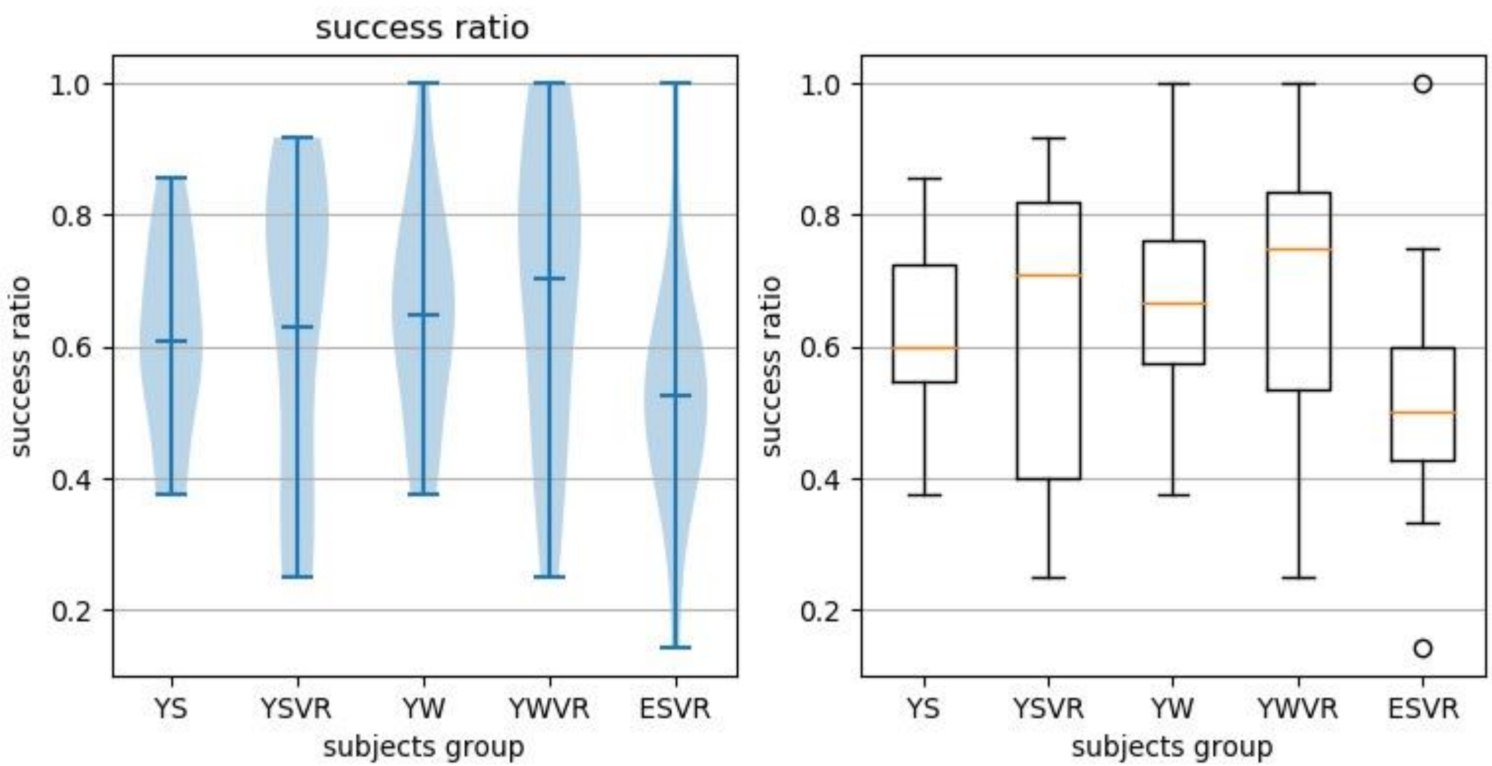




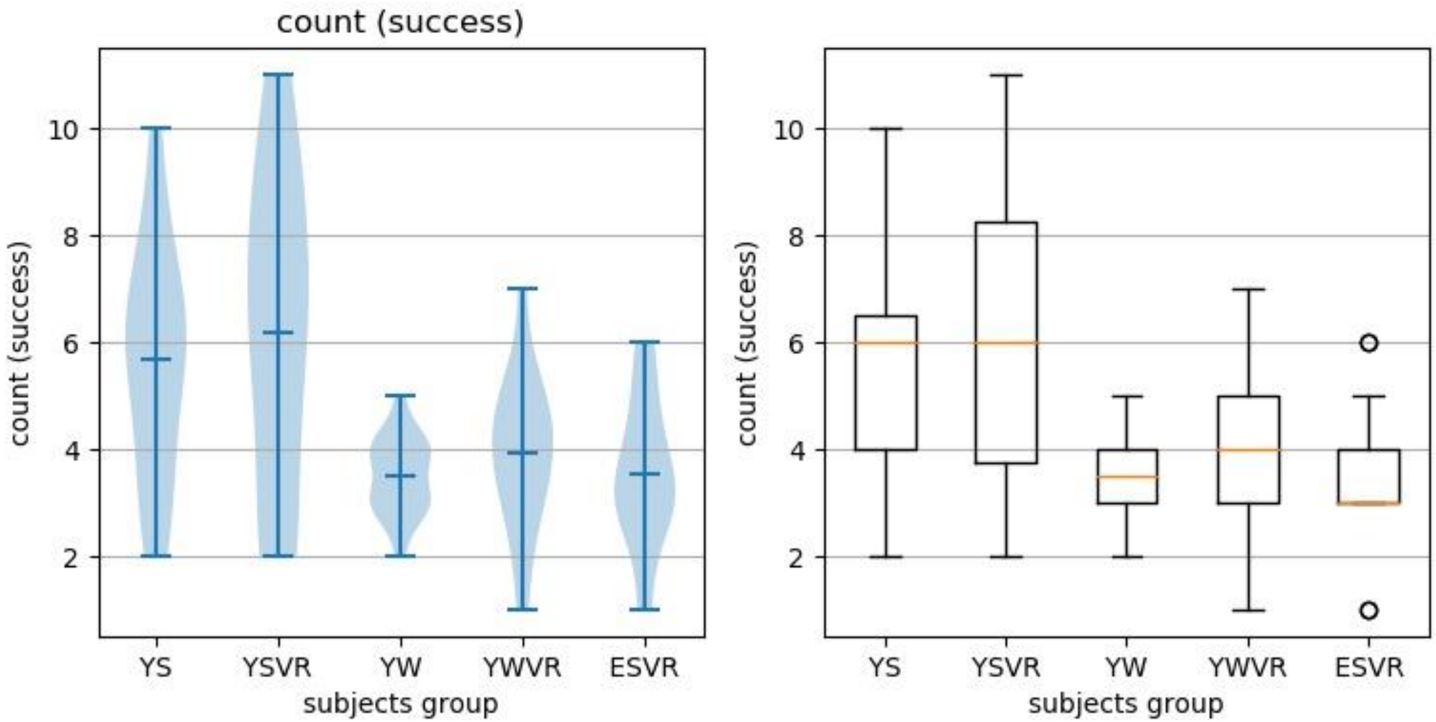
robot wykorzystujący zjawisko teleobecności (telepresence robot)

Success ratio



The success ratio for each group. The largest value is observed for the YWVR group, however statistically significant is the only influence of the age.

Number of successfully completed trials



The number of properly completed trials (success count) for each group. The largest value is observed for the YSVR group, however statistically significant is the only influence of interface type (**S**ITTING vs. **W**ALKING) and age.

Team training for firfighters

Three simulators for firefighters implemented in the Central School of State Fire Service

1. Initial training in the CAVE simulator (20 scenarios)

2. Practical training in the virtual environment (20 scenarios)

Subsequent training stages

3. Practical training in the training container

Innovative training tools for firefighters in the field of internal fires were developed using a training container and virtual simulators. The training container is equipped with a fire chamber with a set of burners and sensors to monitor environmental parameters in the space covered by the fire. The virtual simulators: (1) CAVE and (2) immersive virtual reality simulation – based simulator with the motion capture system and HMDs, complement each other at various training stages. An ICT simulation tool is integrated with the simulators and training container in order to facilitate the evaluation of the training process.

Project CyberFire funded by National Center for Research and Development

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Training simulation

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Training simulation in CAVE

Training simulation in CAVE

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VR-based team training

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VR-based team training

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VR-based team training

VR-based team training

Training container

Container placed in The Central School of the State Fire Service in Częstochowa

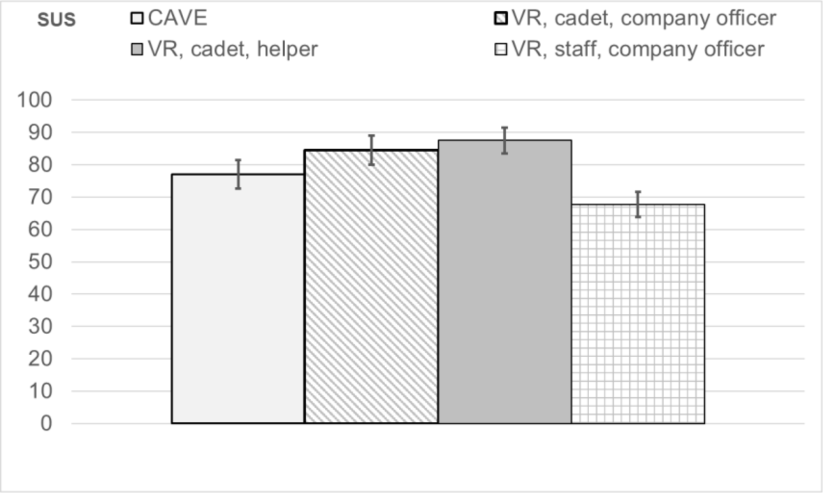
After virtual training more realistic simulators can be used in training process

Training container

Container placed in The Central School of the State Fire Service in Częstochowa

After virtual training more realistic simulators can be used in training process

Usability



Highest usability is observed for cadets training in VR-based simulator.

Project CyberFire funded by National Center for Research and Development

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Machine simulators

Simulators of the folowing self-propelled mining machine developed:

- loader of the copper ore
- drilling car
- anchoring car

Project: Development and implementation of innovative, comprehensive support system for training operators of mobile mining equipment (SMG) for efficient and safe operation in the underground copper mines (partially funded by KGHM and NCBR – National Center for Research and Development).
Project Lider: CIOP-PIB

Simulators developed: loader of the copper ore

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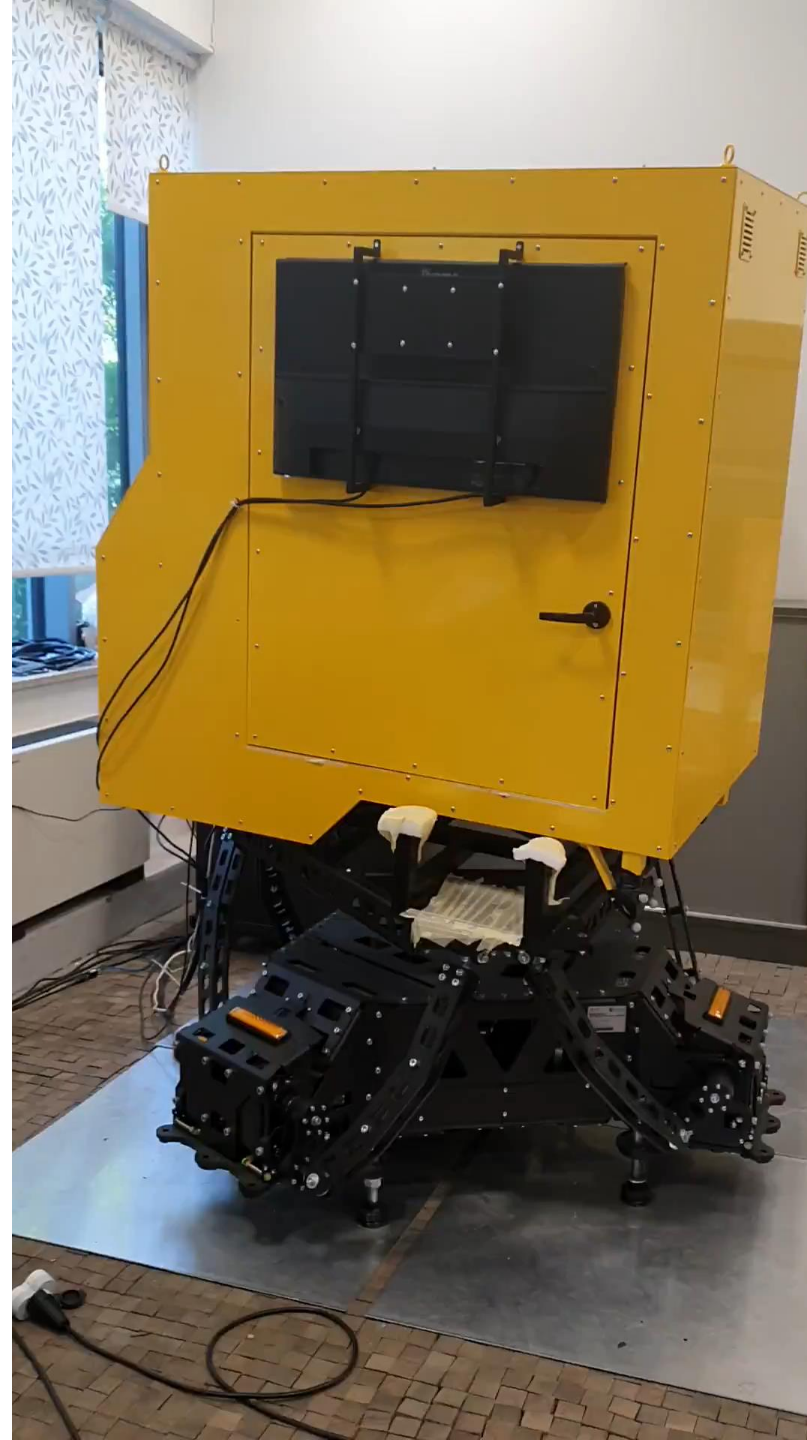
Simulators developed: loader of the copper ore



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Simulators developed: drilling car

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Simulators developed: anchoring car

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Simulators developed: work outside the cabin (pure VR)

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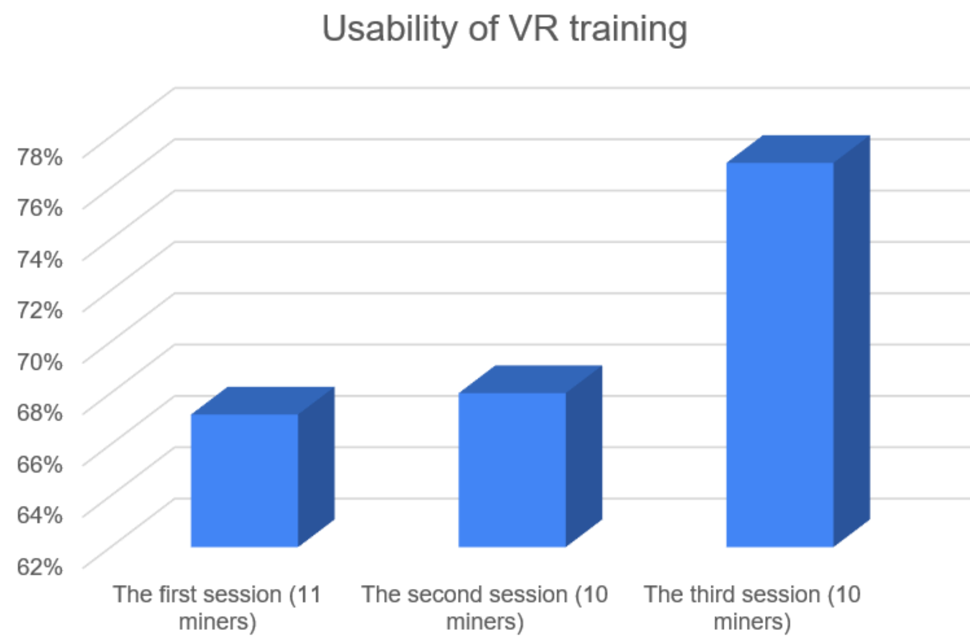
How important is the end user in a research project? (VR)

Three VR-based training sessions were performed with loader operators in KGHM – one of the biggest copper mining companies in the world.

After each session, some operators' remarks were implemented, as a result of the implementation of 20% of remarks (before the third session) a large increase in usability was observed.



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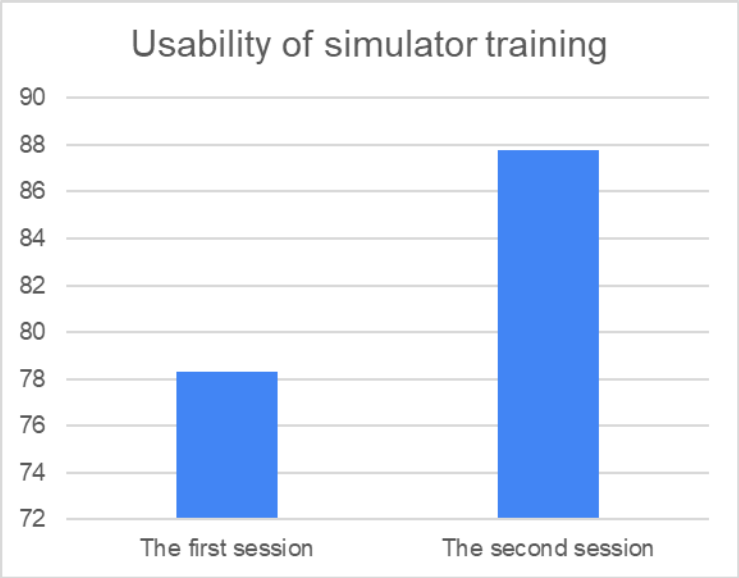
How important is the end user in a research project? (loader simulator)

The usability of training in the simulator is higher. After improvements it reaches 88%.



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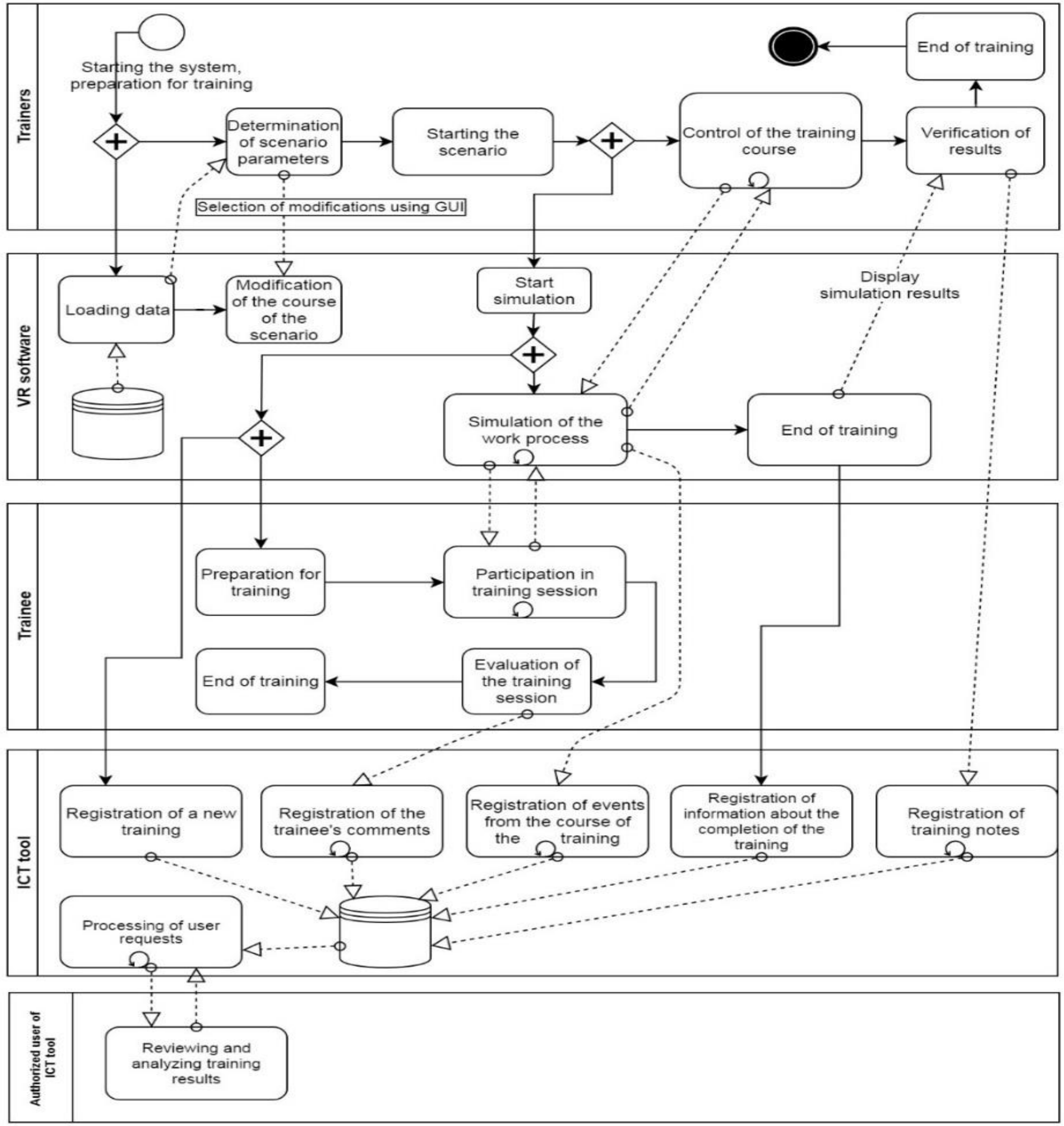
Whats next?

How to improve training process?



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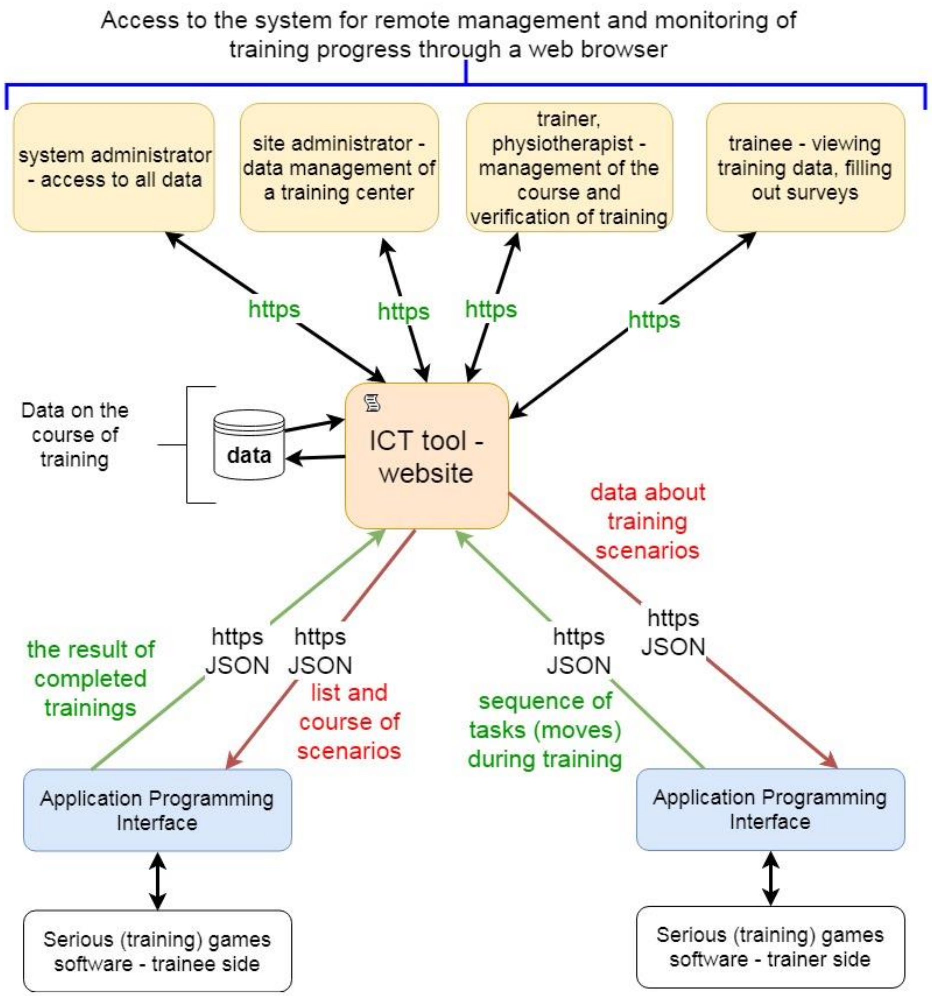

Diagram of data transmission between different users of the supporting the training process system.

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How to improve training proces?

Training tools based on virtual reality, such as machine and vehicle simulators, are increasingly used to train and retrain employees, especially in industries with a high number of accidents at work, such as mining.

The basis of each training simulation is a scenario describing the workflow, which is generally linear with a small number of variants. The effect of this is that the trainee can learn all the elements of the scenario relatively quickly and further training will not have such a strong impact. Training becomes imitative and no longer requires developing skills such as mindfulness in the workplace and recognizing signs of possible dangers.

The solution may be the innovative use of artificial intelligence algorithms (e.g. neural networks) using biofeedback, e.g. (photoplethysmography, EMG, assessment of eye activity, skin conductivity) to modify the training scenario in real time (i.e., create new scenario variants) in an adaptive way, i.e., adapting to the activities performed by the trainee, e.g. by creating (adding) new risks unexpected at a given moment by the trainee, which may appear at a given workplace.

Thank You For Attention!