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Supporting Older Workers in the Context of Industry 4.0 Requirements

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Abstract. The transformation involving the implementation of the concepts of Industry 4.0 can significantly change the labour market, presenting employees and employers with new challenges. Some of these challenges can be solved with the use of technological development, in particular through further robotisation. An interesting example of this phenomenon is the implementation of the concept of remote presence through the use of remotely controlled robots equipped with arms and cameras. This is important for older workers, including those with a muscle strength deficit. However, not all activities can be performed by robots. Some tasks still have to be performed by people. In the factories of the future, cognitive resource requirements may increase significantly. In this respect, appropriate training conducted using virtual reality can help.

Keywords: Industry 4.0, virtual reality, designing training applications, remote-controlled robots

1. INTRODUCTION

Industry was and still is the main engine of economic growth and, consequently, also the increase in the wealth of societies and the quality of life. Technological progress has so far been the basic, and even the main, factor influencing the increase in production efficiency, especially through the automation of production processes [1].

Due to changes in market requirements and in connection with large changes in the demographic structure, completely new challenges and problems arise. It is no longer possible to focus only on technological improvements. It seems that it is now much more necessary than before to focus on people as a central part of the production system, in order to increase overall productivity and compete in globalised markets [2, 3]. People are flexible and creative, and have the ability to reason and make decisions based on intuition, whereas the autonomous systems will not be equipped with these features in the nearest future, enabling replacement of humans by e.g. autonomous robots. For this reason, humans will play a major role in the concept of the factory of the future and Industry 4.0 [4]. Human presence in production is essential to compensate for technological limitations and to ensure the greatest benefits in terms of efficiency, reliability, savings and flexibility [1, 5].

The latest technology can still be a source of support and assistance for workers, especially older workers. This support can be divided into two categories: supporting the performance of physical work (e.g. carrying objects) and supporting the functioning and cognitive resources necessary to deal with the large amount of collected information, characteristic of Industry 4.0. Examples of both of these concepts are presented in this article.

2. TELEPRESENCE IN THE CONTEXT OF USING ROBOTS

It is not always possible to implement full automation and eliminate physical labour. Physical strength deficits can be compensated for by the use of active exoskeletons supported by a set of actuators for the upper and lower limbs, but this is not an ideal solution. An interesting alternative is the use of remotely controlled robots [6] implementing the telepresence concept (Fig. 1). Thanks to the use of virtual reality (VR) equipment, the two-armed robot recreates the movements of the tele-operator, and the real time stereoscopic image from the cameras installed on the robot is displayed in VR goggles, including HMD (*Head Mounted Display*). In this way, the impression of remote (tele) presence is created. The tele-operator has the impression of being not in the place where he is physically located, but in the place where the robot is located. Scientific research on new technical solutions using virtual reality techniques for teleoperation was conducted mainly for the purposes of astronautics.

Fig. 1. Two-armed, mobile, remotely controlled robot implementing telepresence concepts

The decreasing cost of devices used in virtual reality techniques makes it profitable to use them in new applications. One of such areas is teleoperation, i.e. remote control of industrial devices. Teleoperation as a technique that allows the employee to be physically removed from the work environment is of great importance from the point of view of occupational health and safety. Thanks to the use of teleoperation, the employee is not forced to stay in hazardous areas (e.g. with high dustiness, high temperature or explosion hazard).

The use of the telepresence concept to control a two-armed robot has significant advantages over a wearable exoskeleton:

- safety: the operator is not endangered by incorrect operation of the robot, the possibility of the robot tipping over or the presence of harmful factors in the robot's workplace,
- ergonomics: the operator is not limited by the exoskeleton, moreover, they can take a break at any time without the need for the time-consuming process of getting out of and re-entering the exoskeleton,
- the ability to control many mobile robots, operator switching between different robots (this allows you to continue working via a second robot),

- the cost of building a remotely controlled robot should be many times lower (even by several orders of magnitude) than an exoskeleton robot,
- the mobile robot can be much smaller (it does not contain large exoskeleton elements mounted on the operator), so it should be able to move better in rooms intended for people,
- energy-saving and efficiency, longer working time without having to recharge the battery: the mobile robot does not have to carry the operator's body,
- easy adaptation to the terrain in which the robot should move through the use of various mobile platforms: wheeled, tracked, two-legged, multi-legged (e.g. hexapod).

3. SUPPORT OF COGNITIVE FUNCTIONING

The results of the research presented in [7] indicate that older people usually have fewer opportunities to think about and deal with abstract concepts than young people, who often deal with abstract concepts at school or university. This is one of the reasons for the increasing difficulty in coping with new, unknown situations with age, as the cognitive load associated with understanding the meaning of unknown, often abstract, objects or concepts increases with age. As the research results show, older people more often ignore new (incomprehensible) concepts and give an ambivalent or random answer. Moreover, for the elderly, the acquisition of new knowledge is more difficult due to the so-called proactive inhibition [9]. It means that the great amount of previously acquired knowledge (and experience) makes it difficult to acquire new knowledge (including habits, patterns of action, etc.), which is heavily modified or inconsistent with the previously acquired and memorised knowledge. For this reason, it is much more difficult for older people to learn entirely new patterns of conduct and work, and this is exactly what Industry 4.0 is introducing.

According to the observations described in the review [8], the elderly invest their most focused and advanced thinking economically, especially in such contexts that are directly relevant to them, understandable and relate to their everyday life. This is due to the fact that cognitive effort is costlier for the elderly [8].

On the other hand, as shown in the research cited in [10], the elderly have high self-regulatory abilities and are able to consciously and flexibly allocate cognitive resources depending on the requirements of the situation and their personal interest.

This makes it possible to use tools supporting the elderly in the field of cognitive functioning, as long as these tools are of interest to them (e.g. they will take the form of an interesting game).

As shown by the results of research presented in Nature, specially designed games can not only increase cognitive abilities and resources (such as the ability to perform tasks simultaneously, memory and the level of attention) as well as reverse the age-related cognitive decline [10, 11].

Virtual reality techniques can be used to intensely stimulate the functioning of the brain of workers in order to prevent cognitive resources from diminishing rapidly with age. At Central Institute for Labour Protection (Warsaw, Poland), innovative methods of increasing the cognitive resources of older workers are developed, based on the use of the concept of 'gamification', i.e. increasing the involvement of the person participating in the training, by conducting it in a way that resembles a satisfying game to the highest extent possible.

The designed games are focused on new requirements related to the implementation of the Industry 4.0 concept. Modern industrial automation systems generate huge amounts of data. It will be overwhelming to equip every part of the workplace with different sensors and collect and then present such data to the operator. This is the first problem faced by maintenance workers, sometimes given as an argument against the implementation of the idea of Industry 4.0. All such problems cannot be solved through appropriate human-machine interfaces, embedded expert systems or artificial intelligence algorithms. It seems necessary to properly prepare employees so that they are able to cope with the increase in cognitive load at work. This goal can be achieved through properly designed games based on highly immersive virtual reality techniques.

The content of virtual environments of the games being prepared may, and even should, be associated with elements usually associated with Industry 4.0. An example of such an environment is presented in Fig. 2. The illustration shows a robotic assembly line with a remotely controlled mobile two-arm robot equipped with *mecanum* wheels in the foreground. Since human memory is associative memory, it is easier to recreate a memory pattern that is content-linked with other patterns in a neural network. That said, the use of such environments should facilitate the reproduction of acquired knowledge and skills (including cognitive functioning) in a real work environment that it will also be, for example, highly robotic.

An example of a game for practising selected skills in the field of cognitive functioning is presented in Fig. 3. The game aims to develop short-term memory, associate patterns with each other and the ability to switch between tasks and observe various data sources at the same time.

The main task is to arrange geometric solids into slots in accordance with the map assigning the solid to the slot number - the task is modelled on the workplace for the installation of electronic circuits on motherboards in the production of a very short series of electronic devices.

An additional difficulty is that the map of the assignment of solids to slots is visible very briefly and only when the right button is pressed (button # 3).

This forces the storage of the information in short-term memory. The double task is an additional burden.

Fig. 2. A sample virtual environment thematically associated with Industry 4.0

Fig. 3. Virtual environment of an exemplary game related to short-term memory training and the ability to switch between tasks

It is necessary to constantly observe the temperature indicator of the appliance (not shown in the illustration). The task of the trainee is to maintain the temperature within safe values. If the gauge is outside the safe range, i.e. the temperature is too high or too low, the machine may be damaged.

For this reason, the trainee's additional task is to gradually cool the machine (button # 1) when the temperature is too high, or heat it up when the temperature is too low (button # 2).

4. CONCLUSIONS

The development of the Polish economy requires a qualitative change in the industrial competition model towards the use of modern mechanisms for generating knowledge and technology. However, changes in the industry will not be possible without the appropriate staff. Therefore, activities are planned related to initiating, integrating and supporting initiatives aimed at transforming the domestic industry to the level of Industry 4.0. Of particular importance is the creation of a national competence base for the implementation of this transformation. This may be for example, the development of technical infrastructure and competences for Industry 4.0 and activities related to supporting vocational training for the needs of evolutionary changes in industry (e.g. to support vocational training for Industry 4.0). Training applications using virtual reality techniques can be an efficient and effective tool supporting all of the above-mentioned activities.

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Wspomaganie starszych pracowników w kontekście wymagań Przemysłu 4.0

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Streszczenie. Transformacja wdrażająca koncepcje Przemysłu 4.0 może znacząco zmienić rynek pracy, stawiając przed pracownikami i pracodawcami nowe wyzwania. Część z tych wyzwań może być rozwiązana z wykorzystaniem rozwoju technologicznego, w szczególności poprzez dalszą robotyzację. Interesującym przykładem tego zjawiska jest implementacja koncepcji zdalnej obecności poprzez wykorzystanie zdalnie sterowanych robotów wyposażonych w ramiona i kamery. Co jest istotne dla pracowników starszych. W tym z deficytem siły mięśniowej. Nie wszystkie jednak czynności mogą być wykonywane przez roboty. Część zadań musi być nadal wykonywana przez ludzi. W fabrykach przyszłości mogą znacząco wzrosnąć wymagania dotyczące zasobów poznawczych. W tym zakresie może pomóc odpowiedni trening realizowany za pośrednictwem rzeczywistości wirtualnej.
Słowa kluczowe: Przemysł 4.0, rzeczywistość wirtualna, projektowanie aplikacji szkoleniowych, zdalnie sterowane roboty