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Gender-Related Effects of the Augmented Reality Glasses on Cognitive Load

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Abstract

In recent years, the development of Industry 4.0 has led to the introduction of wearable technologies in manufacturing processes. The effects of these new and smart technologies on processes and working people are examined. In this context, both physical and cognitive load formation on people should be controlled. In this study, the effect of the augmented reality (AR) glasses on the cognitive load of the operators in an automotive company was examined. Cognitive load was measured with electroencephalography (EEG). The experiments were carried out with four (two female, two male) healthy and volunteer participants. The cases where the augmented reality glasses were used and not used were compared. The difference between these cases was also examined on a gender basis. Thus, it was observed whether the use of wearable technology has a different effect on men and women.

Keywords: cognitive ergonomics, cognitive workload, augmented reality, automotive industry, electroencephalography

1. Introduction

Wearable technologies such as smart glasses, gloves, and sensors have started to be used increasingly in the manufacturing processes of different industries with the development of Industry 4.0. These novel and smart technologies help operators to increase their working performance and quality of the work. Most of the studies conducted on the topic of Industry 4.0 focuses on virtual reality (VR) or augmented reality (AR)-based smart glasses (Kong et al., 2018).

Augmented reality is one of the prominent technologies in the context of Industry 4.0. AR is a type of virtual environment in which the user can both see the area and objects around. The user can also see the virtual materials composited on the real environment by AR (Azuma, 1997).

AR-based systems have begun to be used in the automotive industry to provide operators real-time information for work or virtual training. It is estimated that these types of novel technologies will generate productivity gains for the automotive industry (Rüßmann et al., 2015). AR glasses are used to assist several tasks like selection and placement of materials for assembly, sending repair instructions to mobile devices, etc. When using AR glasses; changes in attention, distraction, and cognitive load can be measured subjectively (Beckers et al., 2017).

Cognitive ergonomics examines how work and human mind affect each other and aims to determine the effects of the characteristics of human cognition on the quality of work. It also aims to find the workload or stress on cognitive processes of a human (Hollnagel, 1997). The cognitive workload is the degree of mental effort applied by a human to perform one or more cognitive tasks. The mental effort can be measured objectively or subjectively. Electroencephalography (EEG) is a physiological technique that is offered in neuroscience and used for objective and continuous measurement of the cognitive load (Antonenko et al., 2010).

In this study, an EEG measurement was conducted to compare the operators' cognitive workload during finding and sorting the required assembly parts in the automobile assembly line of an automotive company. The possible change in the cognitive load, if any, created by the use of AR glasses during this task was examined on the basis of gender difference.

2. Material and Method

2.1 Participants and experiments

This study was carried out in the real assembly plant with 4 participants (two female, two male) from the company employees who volunteered for the experiments. The EEG activity was measured while the participants were performing the task. Two different experimental cases were created: working with standard procedure and working with AR glasses (Fig. 1).

In the diffusion area where the study is conducted, the operator finds the required assembly parts and sorts them manually according to the order of production. During the sorting process, it is necessary to make sure that the correct assembly part is placed on the correct

field. However, the number of parts in the diffusion area is very large depending on the product variety and volume.
In this process, the use of AR glasses is considered to enable operators to place the correct part in the correct field.

Figure 1: Experimental study

According to the standard work procedure, the operator in the automotive assembly line uses a light warning system and a diffusion paper to prepare the required part in the diffusion area and bring it to the assembly area. The following steps are performed respectively: taking the part from the shelf which one's light is on, putting out the light by pushing the button, comparing it with the diffusion paper and placing it in the required field in the diffusion cart. With the AR glasses, the operator will be able to see the information about which part to take from the shelf and complete the task by scanning the square code on taken part with the camera on AR glasses. Sony Smart EyeGlass was used in the experiments.
Hamilton Depression Assessment (Hamilton, 1960) and Hamilton Anxiety Assessment (Hamilton, 1959) tests were performed before each experiment to determine whether participants had problems of depression or anxiety that might have interfered with the experiment.

2.2 EEG measurement and analysis

EEG signals were measured for two cases: working with standard work procedure and working with AR glasses. Smarting EEG Amplifier and EasyCap were used for recording EEG signals on 24 channels, and BrainVision Analyzer was used for filtering and analysis of EEG data. While the EEG cap was placed on the participant’s head, the electrode impedances were reduced below 10 kΩ using an appropriate amount of gel.
With each participant, one experiment was performed without AR glasses at baseline, and four experiments were performed at two-day intervals with AR glasses. Each experiment was repeated 3 times, and the cleanest data in terms of motion artifacts were considered.

EEG signals taken from the electrodes on the frontal (Fp_1, Fp_2, F_3, F_4, F_7, F_8), temporal (T_7, T_8) and occipital (O_1, O_2) regions were examined. Firstly EEG data is filtered to remove artifacts. In this filtering, beta and gamma waves in the data were also revealed.

It is known that beta waves are associated with motor activities (Pfurtscheller et al., 1996), and visual attention (Wrobel, 2000), and gamma waves are associated with cognitive functioning, learning, memory, and information processing (Abhang et al., 2016). Then the area below the EEG signal graph was calculated. Because the lower P300 amplitude in EEG signals means higher cognitive load (Sergeant et al. 1987), the lower area value was associated with a higher cognitive load.

3. Results and Conclusion

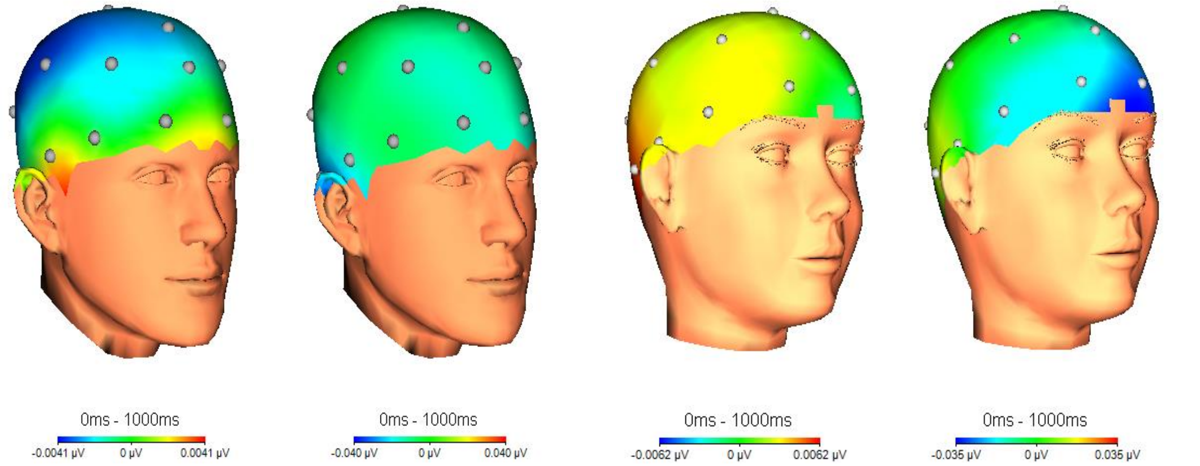
Area values under the EEG graph from mentioned channels were calculated using BrainVision Analyzer and given in Tab. 1. Area calculation was made in a time domain, so the unit of area values are µV * ms. Results of some experiments are also given as head views (Fig. 2).
The absolute values of the areas under the EEG graph were compared for each channel. Experiments, where the absolute value of the area data is highest, were determined. The cognitive load was the lowest in these experiments. The area values of final experiments with AR glasses of 90% of the female participants were found to be higher than the values of the experiments with standard procedure (without AR glasses). And the area values with AR glasses were higher in the experiments of all male participants. Thus, the cognitive loads of both female and male participants were found to be lower when using the AR glasses for the diffusion task on the assembly line.
According to these results, there is no difference between two genders in terms of AR technology usage and cognitive loading. For both women and men, mentally less strain can be achieved by using the AR glasses during the assembly process.

*Table 1: Area values under the EEG graph (µV * ms)*

Experiment		Standard work procedure				AR glasses			
Participant*		1	2	3	4	1	2	3	4
Channels	Fp_1	-1.493	18.895	1.748	-5.624	-34.562	-17.847	-14.602	9.483
	Fp_2	1.596	15.379	0.424	-4.045	-17.959	-29.815	-9.972	6.433
	F_3	2.392	3.623	-1.190	-4.189	-9.115	-29.500	-5.387	4.905
	F_4	2.296	-2.676	-1.645	-3.897	-3.085	-35.813	-11.604	-1.596
	O_1	2.397	6.392	-0.343	-5.243	-23.473	-92.130	-18.662	-17.270
	O_2	3.433	3.249	-0.817	-3.490	-26.913	-51.830	-39.794	-37.089
	F_7	2.427	4.015	-2.525	-3.626	-2.282	-27.801	-14.581	7.423
	F_8	2.212	-13.497	-1.169	-3.483	-13.694	-38.546	-4.529	-4.812
	T_7	4.858	1.742	2.177	-9.626	11.218	-27.186	-10.729	-3.219
	T_8	2.548	49.031	3.237	-6.753	4.036	-4.005	-15.484	-19.975

**Participants 1 and 2 are female and participants 3 and 4 are male.*

Figure 2: Head views of some of the experiments



a) Participant 3 with standard work procedure *b) Participant 3 with AR glasses* *c) Participant 1 with standard work procedure* *d) Participant 1 with AR glasses*

In this study, an experimental setup and EEG measurements were conducted to compare the operators' mental loads during the diffusion task in the automobile assembly line of an automotive company. The purpose is to calculate the mental effect of AR glasses usage for correctly reading the information about assembly parts in this task. Operators using AR glasses were found to be cognitively less loaded. It has been determined that AR technology does not cause an extra cognitive load on operators.

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