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Sexual Cognitive Differentiations in Real and Virtual Educational Environments : Case Study

Chryssi I. Priovolou

***Abstract* – Many researches have accented cognitive sexual differences in real environments with general male predominance in spatial abilities and on the other hand female predominance in verbal abilities. Similar researches in virtual environments and especially educational applicable, do not exist. The aim of this study is to investigate any sexual cognitive differentiation between the participants during their interaction with virtual and real educational environments. For this reason we decided to use the functional brain imaging method of electroencephalography (EEG). Our results showed that both participants used the same cognitive abilities to process the same stimulations. Nevertheless, the two groups differed in perception and in mental processing level. In particular, is thought that males show less visual attention and mental effort during observation of three experimental conditions (two dimensional virtual environment, three dimensional virtual environment and real environment). These findings aim to be used at designing of appropriate educational learning environments and in deeper research of human mind.**

***Keywords* – Virtual Environments, Cognitive Abilities, Sexual Differentiations, Electroencephalography (EEG).**

I. INTRODUCTION

The research of cognitive sexual differentiation has her origins at decades of 1950 and 60 [1],[2]. Although the recent years more scientists are interested in cognitive sexual differentiation research. This tendency has as result the creation of three different scientific options of this subject: a. Psychological with behavioral experimental methods such as psychometric tests, b. Sciences of health in anatomical, neuronal structure and functional level, c. Cognitive science in brain functional and brain organization level with the use of neuroimagining techniques just as present research.

Cognitive sexual differentiations are distinguished in two basic categories: **a**. Spatial abilities where males outperform and **b**. Verbal abilities where females outperform against males [3], [4], [5]. In spite of these cognitive patterns, there are also subcategories of cognitive abilities which present different patterns of sexual differentiations. For instance, in spatial memory and spatial visualization (object location, and mental recall of objects location) females are presented to outperform and on the other hand males outperform in verbal fluency and verbal memory under specific circumstances [6], [7], [3]. The finding of these cognitive sexual differentiations guided to express the assumption that the existence of these differences may be due to morphological brain differences between males and females [8], [9], [10], [11].

The most essential of brain imagining techniques which are used for the research of cognitive abilities are Axial Computed Tomography, Magnetic Resonance Imaging (MRI), functional Magnetic Resonance Imaging – fMRI, Positron Emission Tomography (PET) and Electroencephalography (EEG). Electroencephalography is a non invasive and easy to use method, with high time sensitivity and accuracy of msec same order of magnitude of electromagnetic changes in brain function. This is the reasons why we decided to use this brain imagining technique in the present study. The processing of electroencephalographic signs usually concerns the study of spectrum analysis in certain area of frequencies which we call ‘rhythms’. Rhythms are associated with specific cognitive functions. For instance, rhythm theta (4-8Hz) is associated with coherent learning, attention and information retrieval. Rhythm alpha (8-13Hz) is associated with relaxation conditions and mental calmness, while rhythm vita (13-30Hz) is associated usually encounter with alertness. Rhythm gama (>30Hz) is associated with memory functions, attention and items perception.

There are only few researches which use the method of EEG to study the cognitive sexual differences and their results are in accordance with them of behavioral researches [12]. From the category of verbal abilities, verbal memory were mainly studied (storage and reproduction of verbal information) and were detected sexual differences in brain activation as during storange of information in spectrum areas – *rhythms*, theta, a1 and a2 as that during reproduction of information in rhythms a1 and a2 [13], [14], [15]. On the other hand from the category of spatial abilities, mental rotation were studied during which differences were found in rhythms theta, b1, b2 [16] as in a1 rhythm were females higher introhemispheric correlation between right and left central brain areas and lower between right central and frontal brain areas [17].

Other aspects of cognitive abilities which were studied with EEG method is perception of emotions, where some researches did not detect sexual differentiation while some else found only nuances in brain activation [18], [19], [20] and facies discrimination where the differences were focused in vita (β) rhythm of occipital brain areas with greater oscillation in females [21], [22].

Recent years sciences of education are engaged in sexual differentiations given that diagnosticated sexual cognitive differentiations have consequences in learning disabilities [23], [24].

In this scientific context is subsumed the present study which combine the interest of educational sciences for cognitive sexual differentiations with pedagogic exploitation of Technologies of Information and Communication Technology (ICT). ICT were used to study cognitive abilities initially with simple computational environments and then with contemporary methods of virtual reality [25].

As in the real word, in virtual environments the essential hypothesis is the matching of EEG signals with psychological variables such as attention, perception, memory, alertness, mental pressure. In spite of researcher's cautiousness, given that variables are multidimensional and difficult to be identified, brain rhythms of spontaneous EEG have been used to study the relation between brain and behavior in virtual environments despite the fact that the efforts are still in embryonic stage [26], [27], [28], [29], 25], [12].

In this context are deposit the following searching questions: Is it possible to be allocated the neurophysiologic basis of one's state during his interaction with a virtual environment? Is it possible to be estimate neurophysiologic the existence of cognitive sexual differentiations during interaction with an educational virtual environment (EVR)? This study is an attempt to approximate all these subjects.

II. Materials and Methods

Objectives

Main purpose of this research was to:

1. Detect probable sexual differentiations in brain activity between men and women during the observation of three educational environments identical in content. One real educational environment (REAL), a stereoscopic educational desktop virtual environment (3D) and a non stereoscopic educational virtual environment (2D),
2. Detect the credibility of electromagnetic recording and test the system of electroencephalography in correlation with simultaneous operation of virtual reality's system in order to pick up probable 'noise' that will be induced.

In this context were set the following research questions: Is it possible to define the neurophysiologic base of participants while they observe a virtual environment? Is it possible to evaluate neurophysiologically the existence of cognitive sexual differentiations during the interaction with educational virtual environments (EVE)?

B. Participants

The sample was eighteen (18) healthy undergraduate from Primary Education Department, University of Ioannina volunteers. They were separated in two equal in number groups according to their sex (9 females and 9 males). The sample is characterized by homogeneity in cognitive level and in age as it consisted of, aged 19 to 22 years (mean age 20.5) which is consistent with stabilization of alpha brain rhythm (4 - 8Hz), which change since puberty. All participants were consistently right-handed, native speakers of Greek and had normal or corrected to normal vision without certain diagnosed learning difficulties or mental disease. Handedness was confirmed using a battery of Annett handedness questionnaire (AHQ) and also the criterion for consistent right-handedness [30], [31], [32], [33], [34], [35]. None of the participants received any medication or substances that affected the operation of the nervous system and they had not consumed quantities of caffeine or alcohol in the last 24 hours before the experiment.

C. Environments and Procedure

Main purpose of this present study is to compare electrical brain activity (cognitive processing) of men and women with the use of Electroencephalography (EEG) during passively observation of geometrical solids in three different situations; observation of geometrical solids in real environment (REAL), in stereoscopic desktop virtual environment (3D), and in non stereoscopic virtual environment (2D). Geometrical solids were because they are familiar objects to participants, they are educational tools that can be used in various forms and compositions in different training environments and it was easy to make their virtual models totally identical to the real ones.

Virtual environment was designed with Autodesk 3ds Max 2010 and stereoscopic virtual environment (3D) projected on a 22" stereoscopic LCD monitor with a refresh rate of 120Hz using 3D active glasses. The non stereoscopic virtual environment (2D) was identical to the 3D and displayed on the same monitor without the stereo projection. Both virtual environments were identical to the real one.

In order to keep the subjects attention focused on visual stimulations and to reduce 'noise' of EEG recordings, participants were comfortably seated in a darkened and electromagnetically shielded test area, 100cm away from presented environments and at eye level with the monitor, passively observing each one of the environments (Figure 1). Experimental procedure conforms to the code of ethics of the University of Ioannina.

The experiment took place in three stages. Firstly, participants answered in a questionnaire about personal and demographic information, and then they had a short interview with the researcher who explained them the method of the research and the function of electroencephalography. In the second stage participants interact with three experimental environments and at the last third stage participants answered a questionnaire designed by researchers in order to detect spatial memory differences between the two groups (men and women).

The stimulations were a square, a pyramid, a sphere and a polygonal cylinder which all had wooden texture, they were set on a light grey table, at the participants' eyes height (Figure 2) and the virtual solids were based on the real ones like also the background which was light grey as the laboratory's wall and were presented in a computer screen (Figure 3).

During the task participants watching passively the three environments while electrical brain activity was recorded by an EEG recording system. The EEG recording was contiguous and during spectrum analysis were examined the basic brain rhythms theta (θ) (4 – 7 Hz), lower alpha-1 (a1) (8 – 10 Hz), upper alpha-2 (a2) (11 – 12 Hz), beta (β) (13 – 32 Hz).

Before the beginning of EEG recording participants had a few minutes in order to feel comfortable with the sense of electrodes, to relax and to reduce the eye blinking (basic reason of noise in EEG recording).

During the whole experimental procedure participants were recommended to avoid unnecessary movements that could cause artifacts during EEG recordings as well as any form of speaking and move of head muscles (e.i. murmur, interjection, bruxism, mops and mows etc).

To avoid appearance of weariness to participants between the three experimental conditions (three environments 2D, 3D, REAL), intermediated few minutes of relaxation. Participants would ask for a break during the experimental procedure if they felt malaise, weariness or another unpleasant feeling in order to feel comfortable again and to continue the experiment.

During the presentation of the three experimental conditions (three environments 2D, 3D, REAL), were dominating the same conditions excepting the presentation of 3D environment during the observation of which participants were wearing stereoscopic 3D polarized glasses and in the laboratory the lights were off (Figure 4).

Firstly, they observed the REAL environment in order to feel familiar (comfortable) and modify the possible sense of stress that may have, then the non stereoscopic virtual environment (2D) and at last the stereoscopic environment (3D).

After the completion of the observation of the first experimental task (REAL environment) participants had closed eyes for few minutes while the experimenter was preparing the projection of virtual environments deflecting the items that composed the REAL one.

All the environments were presented to participants in ten (10) repetitions between which the four items were changing their place while the participants were opening and closing their eyes according to the researcher's commands, in order to minimize the artifacts of EEG recording. Participants were also instructed to fixate on the center of the computer screen during the presentation of virtual environments and to the real items that were in front of them on the desk during the presentation of real environment.

During the carrying on of the experimental procedure the researcher wrote down information about participant's behavior (experimental behavior) and about their reactions during the observation of experimental stimuli and during the EEG recording. These notes facilitate the researcher during the final selection of participants and also during the investigation of EEG recordings so as to remove more easily possible artifacts.

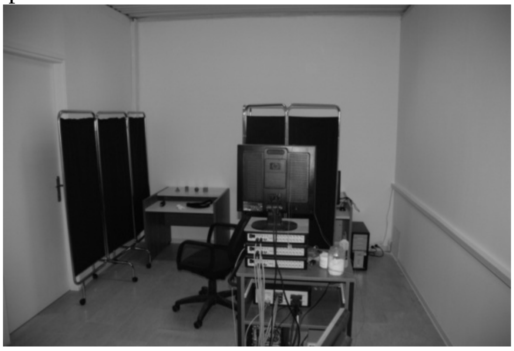

Fig. 1. Laboratory where experiment took place

Fig. 2. Presentation of real educational environment (REAL)

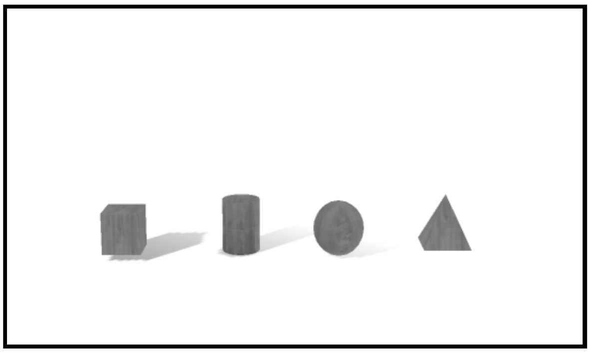

Fig. 3. Presentation of non stereoscopic virtual environment (2D).

Fig. 4. Representation of observation of stereoscopic virtual environment

D. EEG Recording and Analysis

Using electroencephalography (EEG) and technology of Virtual Reality, this is the first study which investigated the neurophysiological underpinnings of cognitive processing and the differences between males and females (cognitive sexual differentiation) who passively looked three different stimulus, one real, one non stereoscopic virtual (2D) and one stereoscopic virtual environment (3D).

Brain wave activity was recorded using the gtec EEG system of 36 channels with 256Hz sampling rate. The digital EEG data acquisition system had a 1 – 48Hz band pass filter. EEG was continuously recorded from 26

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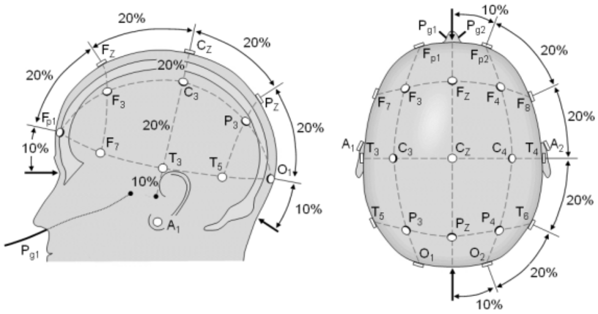
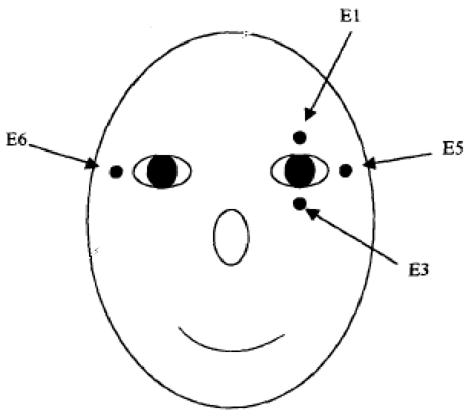
clinquant electrodes from which 20 were up to a particular hood. 19 active unipolar Ag/AgCl electrodes were placed o scalp sites according to 10-20 International Electrode Placement System. Raw EEG data was recorded from positions Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2 (Figure 5a), at a sampling rate of 512 Hz. All leads were referenced to linked ear lobe and a ground electrode was applied to the forehead.

Horizontal and vertical eye movements were also recorded dipolar with four cuplike, golden stick on electrodes placed round the eyes, two at the exterior eyes angles, one upwards and one under the left eye (Figure 5b). An extra electrode used in forehead as earth ground. Linked ears served as the reference lead to head electrodes (positions A1 and A2) (Figure 5a).



a



b

Fig. 5.

Electrode head impedance was kept below 5 kΩ while electrode eyes and ears impedance was kept below 20 kΩ. All the impedance was checked before and after the recording with a recording device (g.Zcheck IMPEDANCE CHECK g.tec GUGER TECHNOLOGIES). EEG epochs were synchronized with the onset of stimuli presentation. To accomplish the best possible EEG recording used conductible crème between scalp and electrodes.

All unipolar recordings (20 electrodes) had as benchmark the ‘VA’ which is the mean of potentials of reference lead ears electrodes. So if reference lead electrodes have egal impedances the potentials mean ‘VA’ arise from the formula: VA = 1/2(VA1 +VA2) (VA1 and VA2 the potentials of two ears right and left). On the other hand when the reference impedances are different according to Choppin (Choppin, 2000).

The EEG data recording and processing accomplished with digital EEG recording system of gtec . For the processing of raw EEG data used the system gBS analyze and data analysis with the software EEG processing developed from our laboratory Educational Approaches to Virtual Reality Technologies (Earth Lab) in University of Ioannina, Microsoft Excel, Matlab and Fast Fourier Transformation (FFT). Band separation made with Fast Fourier Transformation accomplished data analysis in rhythms theta (θ) (4 – 7 Hz), lower alpha-1 (a1) (8 – 10 Hz), upper alpha-2 (a2) (11 – 12 Hz) and beta (β) (13 – 32 Hz).

Finally, the cutting off of EEG trials, the removal of artifacts, the formation of overall tables per rhythm and the formation of brain frequency maps were accomplished by EEG processing software which was developed in Visual Basic and Matlab environment.

E. Experimental Materials and Software

The virtual environments were designed with Virtools Dev Education 4.0 software package and were presented on a 22” LCD 3D monitor with resolution of 1024x768x16 and 60Hz display update rate. For the presentation of stereoscopic virtual environment (3D) were used also the 3dsMax software and 3D polarized glasses from nVIDIA.

F. Results

For the extraction of results, were studied firstly spectral absolute potency maps with colored scale where presented the activated brain areas. The maps were figured separately for every rhythm, experimental group, and experimental condition and are presented overall in Figure 6. All maps use the same color scale where « warm» colors (brown, red) correspond in high rate potency, while « cool» colors (blue) correspond in low rate potency.

From the study of absolute potency maps, the topology extension of brain rhythms theta, alpha, beta and gamma is similar for the two groups (male, female) in three experimental conditions. Difference in topology extension between the two sexes is detected only in the third experimental condition (REAL) for the alpha rhythm where men present activation in posterior parietal cortex and women do not. These observations point to the conclusion that both sexes use the same cognitive abilities to process the same stimulations.

In the matter of brain activation levels in two sexes, we took information from the comparative graphs which present statistical significant differences ($p < 0.05$) of absolute values of faculty for the two sexes and for every experimental condition separately. The findings of these data are presented in Table 1.

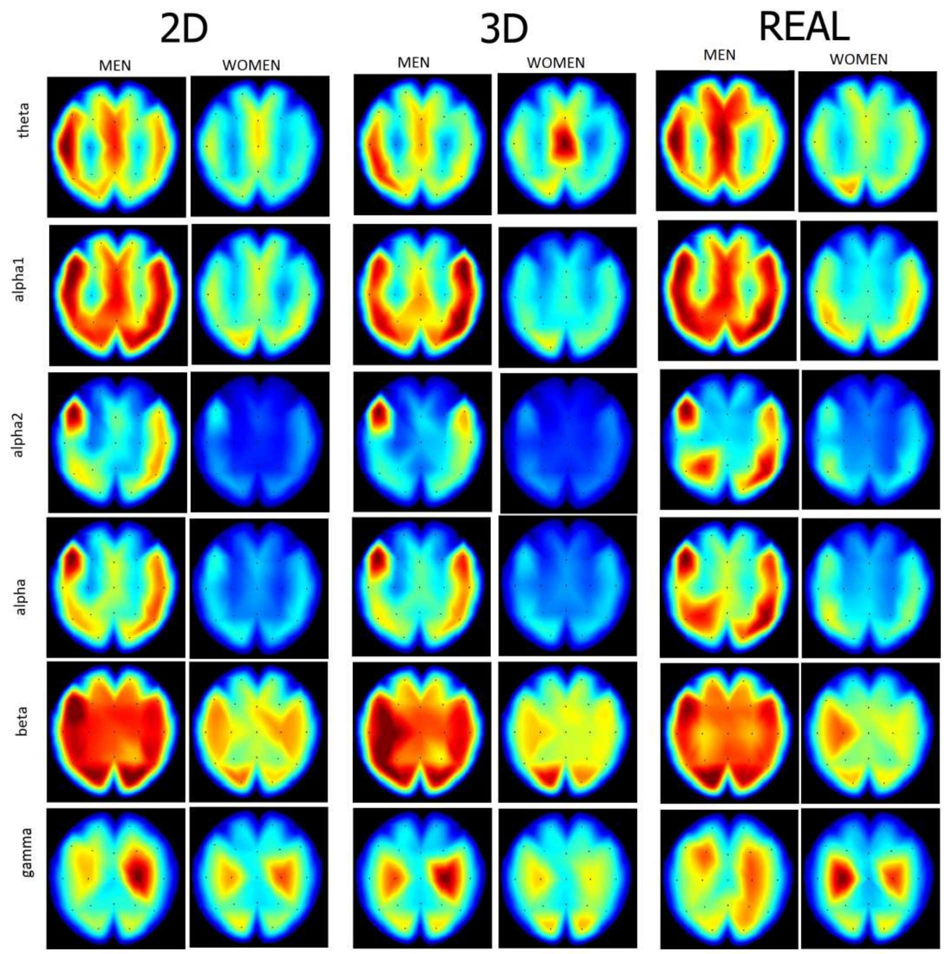


Fig. 6. Spectral absolute potency maps with colored scale (2D: non stereoscopic virtual environment, 3D: stereoscopic virtual environment, REAL: real environment)

Table 1. Brain activation levels

	Men	Women
rhythm theta (4 - 8 Hz)	**2D**: Statistically significant activation of whole cerebral cortex. **3D:** Same activation pattern with 2D condition with exception of right temporal cortex (T_4) and central frontal area (R_z). **REAL**: Same activation pattern with 2D condition with exception of left occipital cortex and left temporal cortex (T_3 and T_5).	**2D**: Did not present any activation predominance in whole cerebral cortex. **3D**: Statistically significant brain activation in right anterior temporal cortex (T_4) and in a central part of frontal cortex (F_Z). **REAL**: Statistically significant brain activation in left occipital cortex.
rhythm alpha (α_1: 8 – 10 Hz) (α_2: 11 -12 Hz)	**2D**: Statistically significant alpha rhythm (also in low α_1 and in high α_2 frequencies) as regards of women, in whole cerebral cortex. **3D**& **REAL:** Same activation pattern with 2D condition.	They did not present any activation predominance in any experimental condition.
rhythm beta (13 -32 Hz)	**2D**: Statistically significant activation beta rythms in comparison with women's activation in whole cerebral cortex. **3D**: Same activation pattern with 2D condition with exception of left anterior temporal cortex where men' s cerebral activation were not statistically significant. **REAL**: Same activation pattern with 2D	Statistically significant brain activation predominance in right anterior temporal cortex only in REAL experimental condition.

	condition with exception of right anterior temporal cortex.	
rhythm gamma (33 - 40 Hz)	**2D**: Statistically significant activation in right occipital cortex, left parietal cortex (C_3) and in whole frontal , prefrontal and temporal cerebral cortex. **3D**: Statistically significant activation in F8, T_4, T_6, P_3, P_4, P_Z, C_4 και T_3. **REAL**: Statistically significant activation in whole cerebral cortex with exception of occipital (O_1, O_2) and bilaterally in anterior temporal cortex (T_4, T_3).	**2D**: Statistically significant brain activation in right anterior temporal cortex (T_6), in posterior parietal (P_3,P_4,P_Z) and in left occipital cortex. **3D**: Statistically significant brain activation primarily in left brain hemisphere and specially in electrodes Fp1, Fp2, Fz, F_3, F_4,C_3, T_5, O_1 and O_2. **REAL**: Statistically significant brain activation bilaterally in occipital cortex and in anterior temporal cortex.

III. Discussion

Present study investigates the differences in brain function and specially in cognitive abilities which present when men and women are in contact with three different stimulations with basic educational content. The three environments present the same stimulations- four geometrical solids- in real environment, in non stereoscopic virtual environment and in stereoscopic virtual environment which is in accordance with previous [36].

The study of the data point to the following conclusions:

1. Men and women process the same stimulations using the same cognitive abilities, as both presented activation in the same cerebral areas, during the three experimental conditions in basic brain rhythms alpha, veta, theta and gamma.

2. The increase of theta rhythm in central cerebral areas has been connected with performance of complicate cognitive functions. From the study of cerebral activation maps, was detected that men apprehend as more complicate processes the observation of real environment and non stereoscopic virtual environment while women apprehend as more complicate process the observation of stereoscopic virtual environment.

3. Theta activation in parietal cortex of men and women during all the three experimental conditions is consistent with the kind of visuospatial stimulations and selected attention, which confirm the conclusions of previous studies [37], [38], [39], [40].

4. Similar activation in men and women between prefrontal and posterior brain areas for rhythm theta during all experimental conditions is in accordance with conclusions of previous studies with performance of visuospatial processes [41].

5. Men drift to accomplish stronger cognitive activity than do women in all experimental conditions, given that they have statistically significant veta rhythm in anterior brain areas which have been connected with high cognitive processing and with construction of mental images [42].

6. Intense gamma activity of men and women in three experimental conditions is in accordance with previous studies conclusions which have connect the presence of gamma rhythm with the response in sensory stimuli and mainly visual and with attention focus in stimuli [38], [39], [43], [44].

7. Women are presented to have more intense perception of stereoscopy in stereoscopic virtual reality condition (3D), given that gamma rhythm has been connected with the perception of stereoscopy in previous stydies [45], [46].

8. Men have significant higher alpha rhythm in three experimental conditions with higher intense in areas of right temporal cortex, which guide to the hypothesis that men sow less visual attention than women and make less mental efforts [47], [48], [49].

9. The intense alpha activity of men in lateral cerebral areas during the observation of three experimental environments commit to conclusion that men come forward to mental representation of external stimulus [50], [51].

IV. Conclusion

In summary, it was noticed that both men and women used the same cognitive abilities to process the presented stimuli which aright became perceptible as visuospatial stimuli. Differences were detected as women are presented to perform more intense processing of primary visual data in stereoscopic virtual environment and also in real environment which they apprehended as more complicated. On the other hand, men are presented to pay less attention and to make less mental efforts in all experimental conditions while in addition they presented to try making mental images of presented stimuli.

The conclusions of the present study, regardless of the fact that they are not easily admitting of generalization, accent the need for designing of virtual educational environments with small degree of complexity, given that simplified environments do not complicate nor women who process in extenso the primary visual data, neither men who create easily the mental images of the simpler stimuli.

The findings of the present study are exploratory and contribute significally at scientific discipline of biological basis of learning and at designing of appropriate educational informatics environments for all. The research is being continued with larger sample and with study of electric brain activity during observation of virtual environments with specific educational context.

V. Acknowledgment

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AUTHOR'S PROFILE

Name:	Chrysi Priovolou
Date of birth:	25.03.1983
Marital status:	Married, two daughters
Nationality:	Greek
Position:	PhD The educational Approaches to Virtual Reality Lab, Department of Primary Education, The University of Ioannina, MSc Cognitive Science
Address:	Xristoforou Nezer 32 Glyfada, Athens, Greece
Tel:	+30 212 101 6 101
Email:	xrisipriov@yahoo.gr
Url:	http://earthlab.uoi.gr/

EDUCATIONAL QUALIFICATIONS

a. Years attended and names of academic establishments

1997-2000	Zosimaia School of Ioannina, Greece
2000-2004	Department of Philosophy and History of Science, National and Kapodistrian University of Athens, September 2005 (1st Degree).
2005-2007	Interdisciplinary Program of Graduate Studies in Basic and Applied Cognitive Science, National and Kapodistrian University of Athens. M.Sc., September 2007
2005-2010	Faculty of Philosophy, Pedagogy and Psychology, National and Kapodistrian University of Athens, September 2010 (2nd Degree).
2007-2014	Department of Primary Education, University of Ioannina. Ph.D.

b. Publications

- Priovolou, C., Bellou, J., N., Mikropoulos, T. A. (2009). “Presence, Cognitive Processes & Electric Brain Activity in EVEs”, Peach Science Fair and Third Peach Working Groups (WinGs) consultation meeting, Dubrovnik, Croatia
- Priovolou, C., Tzimas, E., Zacharis, G., Mikropoulos, T.A. (2010). Sexual Differentiation and cognitive Abilities in Educational Virtual Environments, Proceedings of the 7th Pan-Hellenic Conference with International Participation «ICT in Education», vol.II, pp. 47-54, University of Peloponnese, Korinthos, Greece, 23-26 September 2010.
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