**Technion, the Virtual Reality and Neurocognition lab: Contribution to Euroversity**

**Work accomplished until November 2014 and future workplan**

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Introduction

Recent emerging technologies provide a new potential, exciting field to develop a new frane and theory for learning and teaching in virtual reality. Some examples are the recent Oculus Rift that is a light and wide angle head mounted display. This system differs from previous systems in it view of field: rather than viewing a narrow angle view of the world, as if looking through a narrow pipe, this system provides a wide angle view, which looks and feels natural, as if looking at the physical world, and hence matches the human natural perceptual systems as applied to perceptual processes in everyday-life. Users build mental-perceptual models of the world in a similar way to building a mental model in a sensory-natural environment. This is especially important in physics learning. It has been shown, repeatedly, that learners carry mental models that have been constructed through natural sensory interaction with the environment. These are sometimes consistent with the scientific knowledge, and sometimes not. There is a wide literature that suggests that all types of learners -- students and teachers – demonstarte naïve knowledge in physics, and that the assumption of a 'tabula rasa' in physics is incorrect. Hence, our first assumption, and contribution to the Euroversity project is in pointing out the crucial role of similarity between the perceptual cues in VR and in the physical world, which we term 'ecological validity'. One good example is the technology of the Oculus rift, which in addition to its technological new characteristics, is also inexpensive, and can be bought for less than 300$, and thus applicable to the school system.

IN the previous deliverable we showed that in the spirit of Euroversity according to the goals of WP1 and WP2, we developed best-practice learning environments and designed the technology to provide the tools for optimal learning. Our topics include science and technology teaching and learning content, with a special focus on physics, but practicing also enhancement of learning of general cognitive skills that are applicable across contexts.

More specifically our workplan for 2014 included three components:

1. Completion of experiments and analysis of assessment and evaluation of learning in advanced virtual reality
2. Develop a core list of principles of good practice in virtual reality
3. Integrate our results into a model of assessment of learning in virtual reality.

In the following we describe the results of each of the above components:

### 1. Analysis of assessment and evaluation of learning in advanced virtual reality

We conducted an experiment in virtual reality of teaching the science of measures of blood pressure. The teacher and the students were located remotely. The student/s were able to see the teacher, in stereo 3D as if face to face, addressing each other, including gaze, eye-to-eye interaction

Our virtual reality technology included a patented API developed in the lab of Virtual Reality and Neurocognition in the Technion, headed by Prof. Miriam Reiner, a set of algorithms for low signal-to-noise ratio, and hardware – shutter glasses, 120Hz projector, and specific graphic processors. The voice was natural. We ran the teaching session on 5 groups of 7 students each. The average age was 23.3 and none had any background in the domain taught. The classes were identical in both teaching scenario and setup. Immediately after, students were asked to complete two questionnaires: the first was an attitude questionnaire that addressed the level of comfort and naturalness of the teaching scenario with a wtransported' double of the teacher, and the second focused on the learning outcomes and measured the conceptual changes.

Results of students learning and attitudes showed a and average of high score and low variance on the set of questions related to the naturalness of learning with the face-to-face double compared to realistic face to face (8.2, 0. 5 sd), and a high score on a performance test that included questions regarding the science taught (8.9, 0.7 sd).

In addition we ran an experiment in which we evaluated learning using brain measures of electrical activity, reported in the following.

### 1.1. Evaluation of a learning environment using changes in mental load during learning sessions in Virtual Reality

Most evaluation processes are based on verbal tests or interviews. This leads to subjective evaluation, filtered by the subjects' views. In this study we developed an objective method of evaluation that was based on the measures of changes in electrical brain activity as measured by EEG. The experiment was conducted in the Virtual Reality and Neurocognition Laboratory at the Technion, Institute of Technology, Israel. The experiment group was composed of 12 subjects (without motor impairments) volunteered to participate in a learning experiment. The participants were randomly divided into two groups. The two groups were relatively isomorphic in terms of background and folding skills. Participant's folding skills were based on their self-report and VZ – 2 –Brace (Ekstrom, French, Harman & Dermen, 1976) test results. Both were performed before the learning sessions. Each group was tested in a different remote interaction mode. All the subjects were prohibited to drink alcohol and to have heavy meals for one day prior to the measurements. Subjects were also asked to avoid caffeine up to 5 hours before the experiment. Each subject gave his/her explicit informed consent to the experimental procedure according to Technion ethic code and procedures.

*Double Human Realistic Teacher*

Learning sessions of origami were recorded with the *Double Human Realistic Teacher* software. It is constructed by integrating video, dynamic RGB (Red, Green and Blue) data with data that displays the XYZ coordinates of each point in the space of the modeled teacher. A depth camera (such as Microsoft Kinect) had been used. The camera had two units, each providing part of the information specified above. Propriety algorithms had been used for reduction of signal noise and texture rendering of the 3D model recorded. Both types of data are applied to create a realistic 3-D image that follows the original model teacher performing the origami sessions. The proprietary algorithm allows to save the 3D image in 2D (video) format.

A special classroom was set for screening the *Double Human Realistic Teacher* lessons. (3D image or 2D format) The setup included a Virtual Reality 3D projection system, physiological measurement devices for EEG, and a system for analysis of EEG changes (EEGLAB).

Figure number 1 shows the digital avatar. For reference, we show the 'double' of the projected teacher to a remote site, in the following photo:

Figure 1. A double of the teacher, when teaching origami

The subjects were connected to an EEG system using a cap. the connections were on the cap, and touched the surface of the scalp as shown in figure 2.

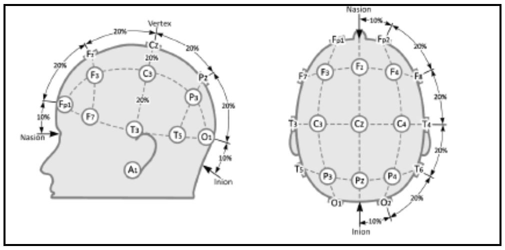

Figure 2. Method of connecting the subjects to the EEG system

We compared the mental load in face to face with a digital projection of a remote teacher in an advanced 3D virtual reality, with the mental load measured during the same teaching session with a video (skype) type of remote communication.

**Results:**

Results show that the mental load during learning with  a three dimensional double of the teacher resulted in lower mental load compared to a 2dimensional similar to skype or second life. Results are shown in the following

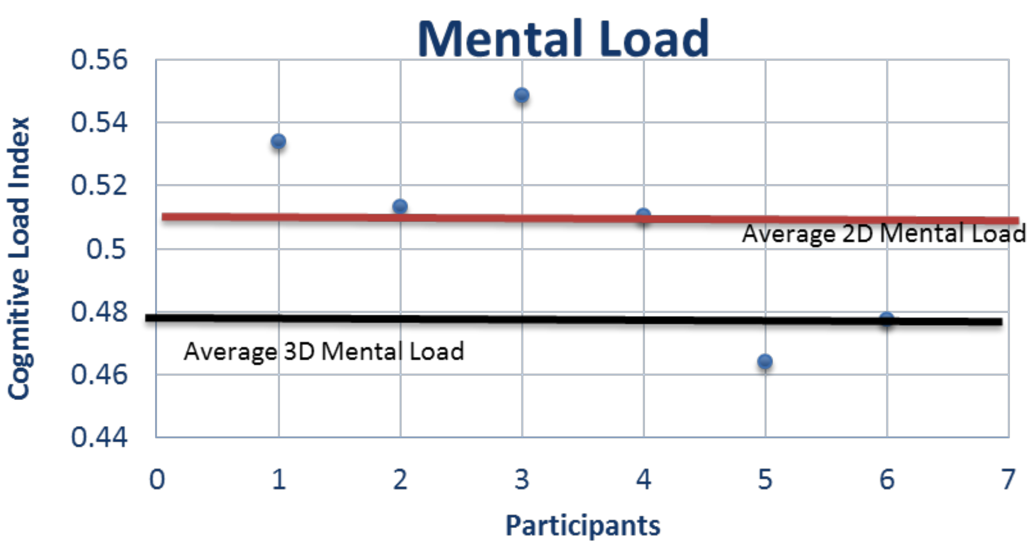


Figure 3: mental load is higher for 2D such as skype or $2^{nd}$ life. Mental load is lower for 3D projection of a face-to-face like virtual reality.

**Summary**

**We have shown here that a virtual reality with 3dimensional presentations is superior compared to 2 dimensional systems in both learning outcomes, attitudes, and physiological objective measures of brain electrical activity. The results suggest that future virtual worlds will be based on 3 dimensional systems rather than 2 dimensional artificial, cartoon like, representations.**

## 2. A core list of principles of good practice in virtual reality

What are good practices of teaching in virtual reality. Based on our results there are three types of conclusions regarding good practice in virtual reality. The first relates to the characteristics of the teaching process, and is common to all teaching good practices, be it in virtual reality or in physical reality; the second relates to the features that are specific to the technology of virtual reality and relates to the question of what are the optimal technologies of virtual reality the match our needs for teaching and learning. The third relates to the specific enhancement of teacher student interaction that is made possible by virtual reality. The following elaborates each of the above.

2.1 Characteristics of the teaching process in virtual reality

As in any teaching scenario, interaction between the teacher and the students is crucial to the practice of good teaching. The ability to see the student, to be attanetive to the facial-body changes in the process of teaching, listening and insertion of questions, the ability to root the teaching into contextualized and situated learning scenarios, changes in representations and provision of the opportunity for integration by the students of multiple representations, the use of branching open questions and discussions rather than closed single-correct-answer- problems, the ability to create discussions and brainstorming, involving students on several levels of personal reflection and expression, are core to this advanced technology for teaching. In science it is especially important to be able to integrate demonstrations that might be virtual or projected from a physical science lab. Lab work, and inquiry –based individual and team work are a central component in the practice of good teaching and must be integrated in advanced virtual worlds. Overall, this suggests that the design of the virtual worlds must match the above needs, in order to apply good teaching practice.

2.2. Optimal technologies of virtual reality that match our needs for good-practice of teaching and learning

The previous section describes what is needed from a theoretical – constructivist point of view. The technological design must allow communication in real time between remote students to apply the social-constructivism, Vygotskyan type of negotiation of meaning for learning, for gradual advanced progress along the zone-of-proximal-development (ZPD) as described by Vygotsky. Thus the technological design must have a component of social network, which are basically now flourishing. This suggest to review and develop a system of principles that apply the social network technology to advanced virtual reality for learning. It further suggests to allow open source information so students can search in real time for problem solving in teamwork, and to allow individual interaction between the etacher and students.

2.3 Enhancement of teacher student interaction in virtual reality

Virtual reality is mediated and controlled by the programmer or by a set of principles. This raises the question whether virtual reality can allow features that are not possible in realistic, physical teaching environments. There are several factors that can be enhanced in virtual reality, by designing  the technology so that specific options are made available to the student and teacher. The first is that the student has access to a wide range of data which she/he can access in real time. The second is that the teacher has access to real-time performance of the student and can support through scaffolding techniques the learning process of the student, by that enhancing the efficiency and reducing the frustration that students might go through. An additional enhancement factor is emotional – through simple available features, mental load and frustration levels can be measured. The teacher might be able to watch these and help students before they get to an emotional anxiety-evolving state.

Multisensory integration has been found to especially enhance learning. When more than one representation is displayed students process the data faster and remember better. The following describes a model of multisensory integration that can be applied to virtual reality.

### 3. A model of teaching-learning in virtual environments

What are the componenets involved in learning and evaluation of learning in virtual reality? We suggest that there are three components to think of. These are described in the figure 4.

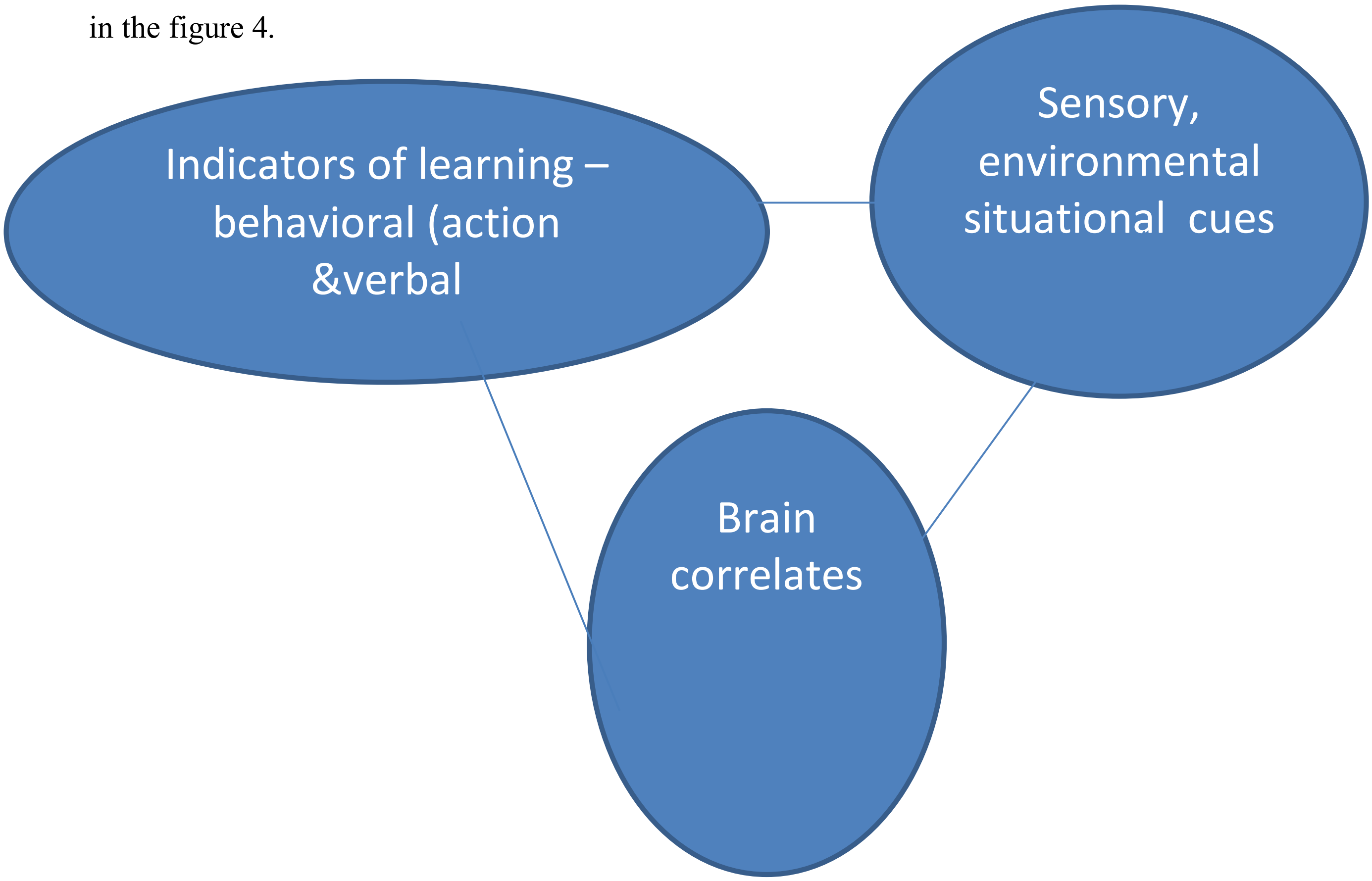


Figure 4: the factors involved in learning in virtual reality: the situational cues of the virtual immersive world; the indicators for learning both actions and verbal; and the brain correlates that are involved in both learning (such as multi-sensory, multi-representational integration) and in evaluation of learning (such as evaluation via EEG).

Such a model would include components that are both physiological, and relate to the conditions of fast processing, and to the theory of learning as expressed in the social-cognitivism approach, social-learning-theory and more recently in the new approaches and findings of neuroeducation.

The first relates to the ability to present multiple representations in a virtual environment that are not possible in the real environment. We developed a mathematical model of integration of multiple representations that suggests that a virtual world should be designed to represent concepts or data in multiple ways. It has been shown the multiple representations results in faster and more efficient integration. The following is a mathematical model that we developed based on several studies of enhancement based on multisensory integration.

$$t_n(s) = t_s(1-\alpha)^{n^{(1+\eta)}}$$

- Here,
- *n* is the number of modalities presented to subject *s*,
- *a* is the fractional reduction in response time for each single modality,
- *h* is the interaction term:
- If *h* = 0 then the modalities act independently, each reducing response time by *a*.
- If *h* is negative, the modalities in combination have less effect in reducing response times than if they each reduced response times independently.
- If *h* is positive, there is synergy between the modalities, so that in concert they have more effect than if they operated independently.

When integrating the multiple representation view with the characteristics of virtual environments, the model that seems to come up is a cyclic feedback model of an adaptive, ever-changing, virtual environment that continuously adapts tot eh students' needs – both emotional and conceptual-cognitive needs, as well as to the needs of interaction with the teacher/s and other students in a team, collaborative learning process. This cyclic model, feedback enhanced, is described in the following:

**Figure 5: An adaptive model of learning in a virtual environment. The environment supports flexibility of representations so it fits both the changing needs of the teacher and the student**