Immersive Platform for Neuroscience Experimental Studies

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Abstract. In this work, we present a computational toolkit to perform neuroscience experiments with people inside virtual immersive environment like a CAVE (Computer Assisted Virtual Environment). Several experiments can be designed, performed and measured for customized virtual scenes. Each participant is exposed to experiences in which they search and collect objects within a three-dimensional space, where they have to use spatial strategies to solve the task. The purpose is to study cognitive functions such as perception, attention, cognition and short term memory.

These tools can reduce the time of experiments formulations and helps to discover mechanisms of attention and spatial and episodic memory. All information about each participant trajectory, the virtual scene configuration, the location of objects in these scenes, and answers to particular questions regarding the experience is collected and presented in.

Keywords: Virtual Reality, CAVE, Data Visualization, Neuroscience

1 Introduction

Computer Assisted Virtual Environment technology or CAVE aims to improve the sense of immersion using immersive virtual environments [14]. This methodology has great acceptance in the field of scientific visualization, engineering, defense and aeronautics, and others [21, 10, 7].

CAVE is implanted in a room, usually cube shape whose walls project computer-generated images. These virtual environments allow working in multiple operating situations similar to the real ones world, and evaluate other atypical situa-

tions or unforeseen risks, always using a combination of visually real scenes and tangible elements, such as knobs, joysticks or controls [6].

Different study protocols about perception, attention, cognition and memory can be constructed using virtual reality techniques. For example, VREX [28] provides a procedural generation of (interconnected) rooms that can be automatically furnished with a click of a button. Researchers can combine different rooms and environments to perform end-to-end experiments including different testing situations and data collection.

Most neuropsychological research has focused on increasing our understanding of component cognitive processes, such as attention, executive functions, memory, and language spatial abilities.

One source of variability in memory performance is hypothesized to be tied to changes in the input to the dentate gyrus (DG). Rodent studies have demonstrated that the DG has a particular role in spatial pattern separation [16, 20]. Stark [27] defines the pattern separation such as the ability to distinguish among similar experiences. Hunsaker [18] placed rats with localized DG lesions in an environment with two objects spaced 60 cm apart. When the animals were later placed in the same environment with the same objects now placed 40 cm apart, DG-lesioned animals (unlike control animals) did not re-explore the objects or environment. These data suggest that the DG-lesioned rats were not able to discriminate between the training and test environments.

Since object-based pattern separation appears to be modulated by the DG in humans, we wondered if these findings could be extended to spatial pattern separation in a RV enviroment. So, we extended these studies to the human, using a task designed to assess spatial pattern separation behavior in a CAVE [3]. In our work we want to present the cave as a virtual reality tool that is used for neuroscience experiments. The idea is to extend to human pattern-separation experiments previously done on rats [15, 30].

This paper presents a software platform deployed on a CAVE environment for carrying out experiments in neuroscience. The idea is to observe and measure how adults responds to 3D stimulus. In the future, the main purpose is to apply this software in neurogenesis understanding [9, 8], studying the short term memory based on objects geo-location correlated physical actvities.

2 Methodology

2.1 Experiments on CAVE

As it was previously named CAVE consists of a closed room wherein computer-generated virtual environments are projected generating the feeling of immersion of the user. Particularly, CAVE installed in PLADEMA Institute is formed by a three meters metal cube-shaped structure, whose inner walls are coated with special fabrics that allow for rear-projection (Fig.1). Four projectors are used to display the image on the front and side walls and floor. Each of the projectors is connected to a dedicated PC responsible for generating the image.
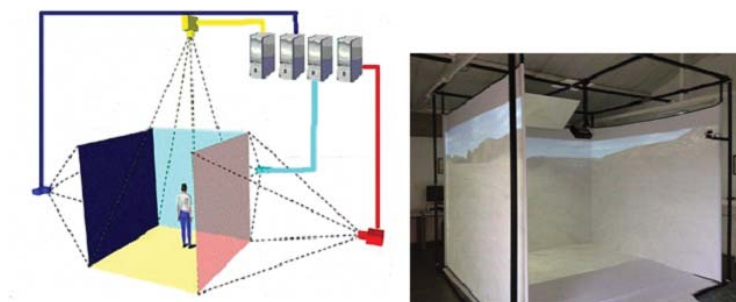
Fig. 1. CAVE installed in PLADEMA Institute.

The projecting scene in CAVE is selected from a set of predefined landscapes. Following, different components are introduced to the experimental scene as the experimental subject, being the pennants, the questions, or the zonings are some examples. A homely joystick is used to move on the scene and interact with applications.

Two types of actions are allowed for the participant:

1. **Collect the pennant.** It is the statement that defines the action whereby the subject will have to search a pennant located in a particular position of the scene.
2. **Locate the pennant.** It is the instruction whereby a pennant is assigned to a subject that should place it in a position in the scene, intermediate or between to the two flags that were collected before.

2.2   Editor of experiments

To perform the testing exercises, an edition tool, that configures individual experiences and presents an immersive virtual environment for each participant, was developed.

With the editor, the number of pairs, the location and the color of pennants and the configurations that the neuroscientists want to evaluate are added: place the pairs of pennants in a circular shape around the center of the arena (Fig.9) or select between different conditions (C1 y C2) during the test execution (Fig.10).

As it was previously stated, the research scene is represented by a wide and flat terrain that the user can tour entirely. There is a mark on the floor indicating the center of the arena to be used a reference point for the beginning of the exercise and distance measurement. The pennants are distributed in a uniformly distance of the center of the arena, according to the scene configuration.

The software has a set of 12 scenarios. The predefined scene shows a quarry like the one shown in Fig.2. The rest of the scenarios have the same place but add shrubs, grass, drums, squares and other elements. The software user can choose between scenes according to the number and variety of objects he or she wishes to view.
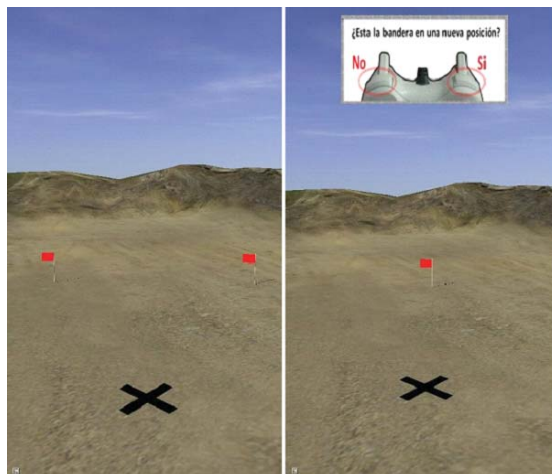
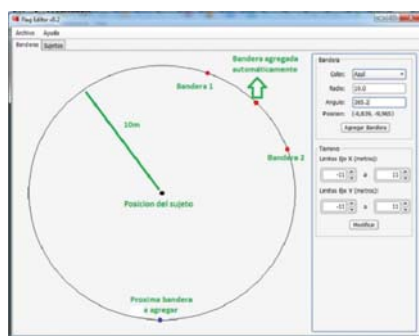**Fig. 2.** Beginning of the exercise (left).Execution of the condition 2 (right).

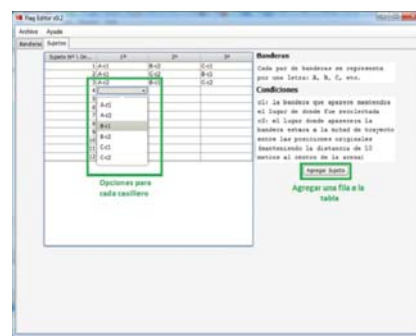**Fig. 3.** Scene Editor Interface: location of pennants.

Fig. 4. Interface Scene Editor: selection of patterns.

In addition to the module in charge of the design and visualization of scenarios, the tool has a module that is in charge of the logic of the execution of the experiment. This means the sequence with which the elements of the scene (flags and boxes with questions) appear and disappear according to the movements of the participant.

We are currently working to develop a tool that allows us to configure a greater number of parameters in order to be able to perform an endless number of experiments.

3 Formulation of experiences

At the beginning of experimentation, the participant is directed to the center of the virtual scene and makes a practice test executing an instruction set, that

was previously given to accomplish the test objectives. Among others, the actions that perform an experimental subject on the immersive virtual scene (o setting) are displacements to either explore, collect or drop different objects. All these actions are performed using a standard joystick.

3.1 Experiments based on pattern separation

In these experiments, the participant appears in an open space with weak environmental sound. To move or collect pennants (until three pairs: A, B, and C) a joystick is used. The test places the pennants, circularly, at approximately 10 meters.

The partaker must collect three pairs of pennants that form angles of $50°, 80°$ and $120°$ with each other relative to the center stage. Such order corresponds with the pairs A, B y C respectively. Table 1 presents the studied alternatives posed to each participant.

Alternative	1st test	2nd test	3rd test
A1	50°	80°	120°
A2	80°	120°	50°
A3	120°	50°	80°
A4	50°	120°	80°
A5	80°	50°	120°
A6	120°	80°	50°

Table 1. Alternatives of separation of objects.

The partaker proceeds with each pair of pennants as follows: collects the first pennant, returns to the center of the arena, and repeats the same actions with the second pennant. Then, the system locates a new pennant within the scene. Now, the subject answers if the pennant is on the same position as any of the ones previously collected (see option C1 on Fig. 5), or midway between the two original positions of the pair of pennants (see option C2 on Fig.5), while keeping the distance of 10 meters to the center of the arena. There are no variations in the remaining experiences.

In Table 1 the different alternatives (A_i) can be observed, according with the order in which the pennants appear according to the angle. Thus, for alternative A_1, the two pennants will first appear separated by an angle of 50 deg; after the participant completes the 1st test, the flags will appear separated by an angle of 80 deg; and for the third test the pennants will be separated by an angle of 120 deg.

Protocols (or paradigms) are defined to consider in each simulated experiences. They establish alternative location of objects within the virtual environment, according to the order of appearance of the pairs of pennants (pair A, B and C), and the location of appearance of the new pennant (options C1 or C2). The protocols considered are as follows.
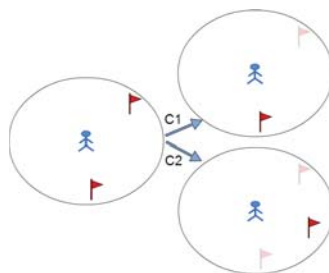
Fig. 5. Posibles ubicaciones de los banderines al responder la pregunta.

To evaluate the memorization of the participant, within dialog integrated boxes into the scene, some questions are formulated. Each question has its correct answer and it is not informed to the subject, it only serves to the neuroscientist to validate the answer or evaluate the experiment with this particular subject.

Finally, while the participant is performing the virtual experience within the CAVE, their movements are automatically recorded: the position of the pennants that has to collect (or move), the distance between them at the beginning and end of each activity, among others data.

3.2   Characterization of the participant behavior

To characterize the overall behavior of the subjects, different agreed metrics are represented and described below.

- **Total effective time:** the time the subject take to perform the test.
- **Individual routes:** participant's positions are recorded along the experiment. Considering the amount of evidence, tours are organized in order. The output is a set of coordinates and grouped data by subject and route. This representation allows observing how people have moved on scene.
- **Response time:** Between each test, the person takes some time to respond to the slogan. This time is calculated as the average delay time to answer the three questions.
- **Characterization of the route:** One idea is to characterize the movement of participant in relation to the objective; particularly if they move (or not) in a beeline from the scene center to each pennant. To indicate quantitatively how a person moves, it is calculated as the average distance to the ideal straight (calculated using linear regression). To characterize the way, it is said that if the average distance is low, the route tends to be linear; whereas if it is high, it presents nonlinear forms.
- **Success rate:** It is estimated from the number of right correct questions over the sum between the correct and incorrect questions.

4   Results

Eight people have involved,-two female and the others males-, between 24 and 45 years old among which there were students and graduates of the Engineering Systems career of the Exact Sciences Faculty of UNICEN.

Participants performed the different exercises on an immersive virtual environment. After analyzing the experiments, the information was processed in order to characterize the behavior of the participants. To do this, the application builds the effective visualization of the routes from the information collected in CAVE.

The partaker is located in the scene center. From this point, the partaker begins to move to collect the pennants. Each route is projected on the Cartesian plane as shown in Fig.6. The route path display for each participant is constructed using the JFreeChart[4] library. In each route (going and forth to the starting point) collects a pennant; each iteration consists of two trajectories and a question about the location of the new pennant. The colors of the graphics grouped the tests performed on each iteration.

Although the set of samples is dramatically reduced, from Table 2, it follows that S0, S2 and S5 have correctly answered all the questions. However, they consumed very different times. This may be because of the expertise at using that each participant has the joystick, or the alternative separations of the pennants, S0 presents excessively abrupt direction changes in the followed trajectory while S2 and S5 remain almost rectilinear movements (see Fig.6).

(a) S0   (b) S2   (c) S5
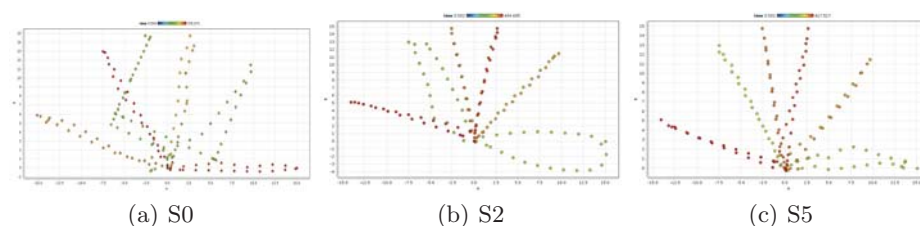
Fig. 6. Participant displacements in the virtual environment.

If we analyze the data answers times (see Table 2 and Fig.7), we find that in most cases the subject correctly answers the first question. Incorrect answers correspond to subjects that performed the alternatives A1 and A2. Therefore, the separation of the pennants on those who have answered the question is 50° and 80°.The same applies to the second question, the subject that answers wrongly performed the A1 and A2 alternatives, but the angle separation between pennants is 80° and 120°.The third question was answered wrongly by 2 of 8 individuals, who perform again the A1 and A2 alternatives with the pennants separated by 50° and 120° angles.

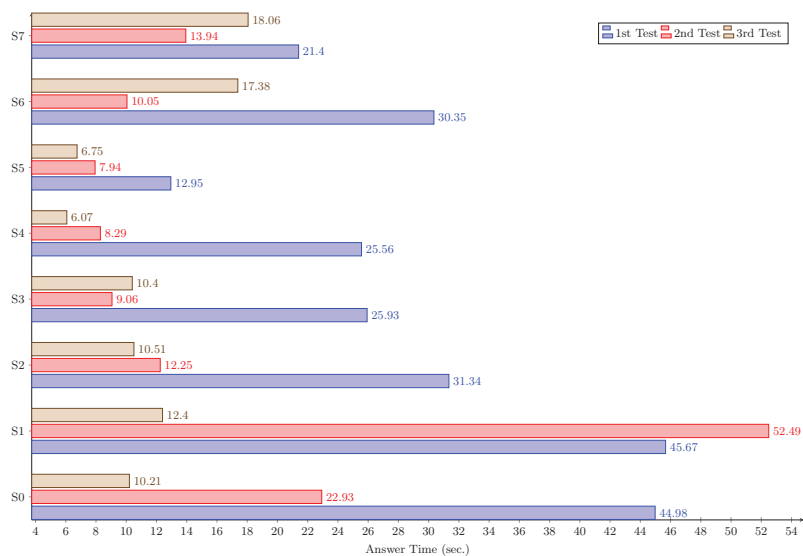
[4] http://www.jfree.org/jfreechart/

Fig. 7. Answer Time for each participant

5   Conclusions

A kit of computational tools was developed for neuroscience experiments in virtual environments to process the information that comes from actions performed by each participant and, finally, elaborate pertinent conclusions. Specifically, the scenes are projected onto the CAVE where participants explore, gather or locate different objects. The tool design can be extended: add new stages to create new metrics, apply filters to discard irrelevant information or quantify ratios between different variables of interest through their correlation. For example, one of the ideas was to measure the correlation between the time response and the difficulty of the exercise. Another idea is to analyze the movement within the scene when

Id	Alternative	Time means (sec.)	Answers time (sec.)			Success		
			1st	2nd	3rd	1st	2nd	3rd
S0	A1	26,04	44,98	22,93	10,21	1	1	1
S1	A2	36,85	45,67	52,49	12.40	1	0	0
S2	A6	18,04	31,34	12,25	10,51	1	1	1
S3	A1	15,13	25,93	9,06	10,40	1	0	1
S4	A2	13.31	25,56	8,29	6,07	1	0	1
S5	A6	9,22	12,95	7,94	6,75	1	1	1
S6	A1	19,26	30,35	10,05	17,38	0	1	0
S7	A2	17,80	21,40	13,94	18,06	0	1	1

Table 2. Shows the delay responding times and the successes.

the person has no history of controls use as the joystick, or experience in 3D environments.

On the other hand, it is planned to extend the application to provide support to display data in different graphic types under different configurations, being able to record demographic data of the subjects to establish a relationship between the data produced by the CAVE and the demographic data of the subject.

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