Virtual Reality as a Tool to Study Embodied Cognition

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I. State of the Art

Contemporary cognitive and social robotics share important scientific questions with the fields of psychology and neuroscience [1, 2]. How does an artificial machine can learn to safely manipulate an object? While roboticists try to build machines performing as efficiently as humans, neuroscientists try to understand how the brain works and leads to intelligent behaviours. During the last 10 years, multiple novel tools to study human cognition appeared on the market, such as eye tracking and motion capture systems. Nowadays, modern Virtual Reality (VR) systems are intensively used in academia to investigate human behaviours. The most beneficial feature is that they provide both laboratory settings (well-controlled experiment) and near to ecological environment. However, VR can provide much more information than academics do collect, such as kinematic data and neural data when coupled with Electroencephalography (EEG). The aim of this extended abstract is to describe existing VR paradigms and our original VR setup coupled with EEG, used to study how humans build novel representations of objects and actions. The goal of our project is to provide a better understanding of the neural bases of novel objects and actions representations.

Recent advances in VR technology allow us to go beyond the initial perspectives. For instance, now VR is used to investigate how users' process their own space. Spatial cognition is important for psychologists as well as cognitive roboticists (eg. the importance of peripersonal space for a robotic arm safety [3]). Using an immersive virtual reality paradigm, Iachini et al. [4] investigated what are the distances necessary for a user to be comfortable interacting with a virtual avatar or a robot. Another VR study showed that motor affordances provided by everyday objects (eg. the handle of a cup) are processed only when the object is situated in the reachable space [5]. A similar VR environment was used [6] to establish how object knowledge is also accessed automatically upon viewing tools and other manipulable objects when they are within reach. This means that our implicit affordances perception and manipulation knowledge are modulated by the stimulus position in the space. The following research from the same team showed that neuronal μ rhythm (8-13 Hz) represents a neural signature of this affordance processing [7, 8]. To do so, the authors used goggles with projected stereoscopic images, which differ from our approach using full head-mounted displays.

Such investigations have been possible because VR now goes beyond passive viewing, and can be used to represent virtual tools that the user can manipulate by proxy through physical tracked controllers. This means that the user can manipulate and affect their virtual environment, a central tenet of embodied cognition. This approach allows us to examine some of the basic properties of the embodied approach through extract control methodological factors (eg. properties of the stimuli), that are robust, and repeatable. They also allow us to overcome significant logistic issues (eg. placing and removing an object manually at different distances from the participants thousands of times) that tend to make physical experimental studies unfeasible, or underpowered.

II. Method

As described briefly, VR is a modern tool to study how the human brain process objects and guide their manipulation. Our lab investigates these cognitive processes using a VR setup coupled with EEG recordings (Figure 1). Using two interfaced computers and a VR head-mounted display placed on the top of an EEG cap, the EEG recordings are synchronized with multiple events happening in the virtual environment. Our setup allows us to track the neural activity underlying the recognition of objects (ie. a stimulus onset) and motor control (ie. movement onset and grasp onset). Hence, the setup also provides the opportunity to investigate the emergence of novel object representations through the use of novel objects (Figure 2).

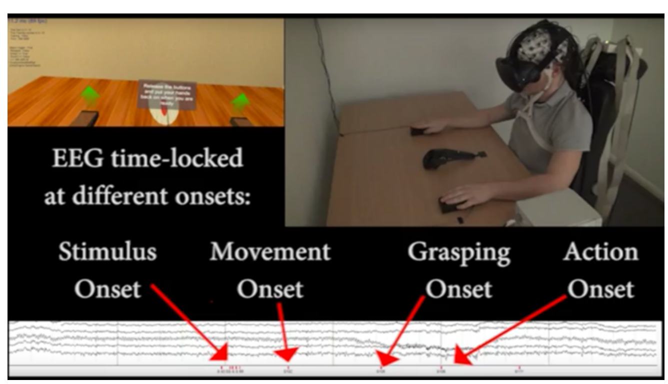

Figure 1 Representation of a virtual environment (top left) where the participant interacts with a controller (top right). Participant's EEG is synchronized to the key events of the experiment (bottom). Stimulus onset: the participant processed the apparition of an object. Movement onset: the participant released a hand from a button situated on the table. Grasping onset: the participant grasped the controller at a location A. Action onset: the participants placed the controller on a location B.

Figure 2 Example of 3D models created by the researchers that participants learn to manipulate.

Finally, as VR controllers are tracked in real-time by two cameras, the setup allows the researcher to track how participants manipulate them. For instance, the position, the rotation and the velocity of the controller can be tracked in the space during the transportation of the controller from a location A to a location B (Figure 3).

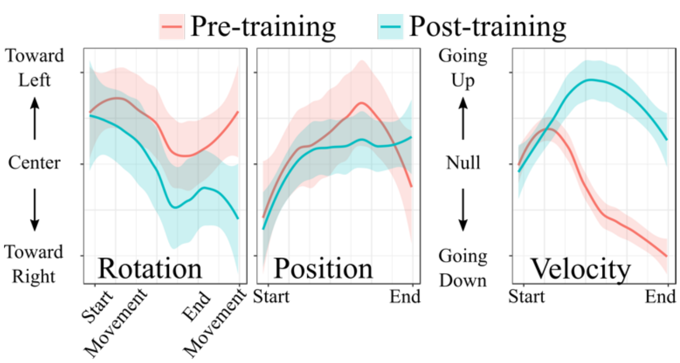

Figure 3 The task of the participant was to transport an object from a location A to a location B. In the middle of the experiment, participants perform another motor task (training). The tracked VR controller allows to record and compares the rotation, the position and the velocity (single axis presented) during the transport task (ie. hand movement) before and after the motor training. Here, performing a motor training influences the motor control of the transport task afterward, especially the velocity of the hand movement.

III. Conclusion

Coupling VR with EEG techniques allowed our team to investigate the neural activity underlying the recognition of novel tool and the selection of learnt tool use [9-11]. As investigated in cognitive robotics, we use this setup to understand how humans build representations of novel objects and actions. To conclude, the number of applications of VR goes beyond the primary goals expected twenty years ago. Most recent research in cognitive science and related fields couple VR with other well-known technologies, such as EEG techniques in order to overcome methodological limitations and therefore extend their scientific potentials.

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