Short Paper

Using a VR social network during awake craniotomy to map the social cognition.

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Abstract

**Background:** With awake craniotomy, it is possible to temporarily inactivate regions of the brain using direct electrical stimulation, while the patients perform neuropsychological tasks. If the patient shows decreased performance in a given task, the neurosurgeon will not remove this region, so as to maintain all brain functions.

**Objective:** We are evaluating the safety of a virtual reality headset (VRH) during awake craniotomy (ClinicalTrials.gov: NCT03010943). The objective is to describe our experience with a virtual reality (VR) social network and discuss future applications for perioperative mapping of nonverbal language, empathy and theory of mind (ToM).

**Methods:** During the wound closure, different VR experiences with a VRH are proposed to the patient. This paper aims to explore interaction with the neuropsychologist’s avatar in virtual locations using a VR social network as an available experience.

**Results:** 3 patients were able to experience this. Despite some limitations due to the patient position during the operation and the limitation of nonverbal cues inherent to the app, it was possible for the neuropsychologist to communicate as an avatar with the patient and explore gesture communication while wearing a VRH.

**Conclusions:** With some development, VR social networks could be used in the near future to map social cognition during awake craniotomy.

**Keywords:** virtual reality; neurosurgery; social cognition; awake surgery.
Introduction

Social cognition includes all complex cognitive processes involved in social interaction such as non-verbal language (facial and bodily nonverbal cues, as affective prosody), empathy and theory of mind (ToM) Following brain surgery, impairment of decoding nonverbal cues, such as expression of facial emotion, eye gaze, body gesture and prosody can all lead to ToM deficits. The patient has difficulties with understanding humor and metaphors as well as conceptualizing, understanding or knowledge, thoughts and beliefs, emotions, feelings and desires, behavior, actions and intentions of another person. In recent times these sequelae were largely misunderstood by neurosurgeons, and compared to language or executive functions post-surgical impairment, with few evaluations having been published concerning social cognition[1–6].

As it was done for language, it is now possible to propose a substrate to social cognition based on parallel and interactive large scale distributed brain networks[7]. However, unlike language, this substrate cannot be reliably localized on anatomical criteria alone, mostly due to the inter-individual variation. Individual brain mapping by direct electrical stimulation (DES) during awake craniotomy is therefore essential. The procedure has been well documented [8]. Briefly, it is possible to temporarily inactivate regions of the brain using DES, while the patients perform neuropsychological tasks. If the patient shows decreased performance in a given task, the neurosurgeon will not remove this region, so as to maintain brain function.

Compared to motor or language mapping, nonverbal language mapping is not yet to be performed. This is due to the difficulties involved in adapting classic bedside tasks to awake surgery conditions.

In 2014, aware of these limitations, we started to explore the use of virtual reality (VR) during awake craniotomy with the patient wearing a virtual reality headset (VRH). We have previously developed an application for VRH to explore visuo-spatial cognition[9]. We are now performing a larger study evaluating the tolerance and safety of a VRH and 3D immersive experiences in patients having awake craniotomy and brain mapping by DES. The aim of this paper is to describe one of the VR experiences, the interaction with an avatar using a social VR platform and to highlight its advantages, limitations, and future applications for perioperative mapping of social cognition.
**Methods**

This is a single center, prospective, open label trial (ClinicalTrials.gov base identifier: NCT03010943), in compliance with regulation and ethical guidelines for clinical research. All patients signed a written informed consent. Inclusion criterions are: patients > 18 years old, hospitalized in the department for a tumor or any type of surgical lesion near the language region of the brain. Exclusion criteria were all contraindicate to an awake surgery (cognitive impairment, aphasia, morbid anxiety). The main objective is feasibility and safety.

This study is performed using a Samsung Gear VRH combined with a Samsung S7 smartphone (android platform), and headphones.

After general and local anesthesia the patient was positioned lying on their side, with a rigid pin fixation of the head. Once the craniotomy was completed and the dura opened, the patient was woken up. EEG signal was recorded through a subdural electrode. After the cortex was exposed, the language mapping was performed by the neuropsychologist, with an image denomination task on a digital tablet. The mapping took place as previously described [10,11]. DES was applied with a bipolar electrode delivering a biphasic current (60Hz, 1ms pulse width, current amplitude ranging from 2 to 8 mA).

To prevent interference with the routine procedure of awake craniotomy and language brain mapping, we decided to duplicate the image naming task viewed in the VRH in 2D, and then stereoscopy (3D) (app based on Unity 3D software with an interface allowing VRH communication via a computer and a Bluetooth connection). Further relaxing VR experiences are proposed at the end of the tumor resection while the wound closure takes place. These options include interaction with the neuropsychologist’s avatar in virtual locations with this option being the purpose of the present paper. For this experience, we used the application VTime, a social network in VR[12]. This application allows users to create an avatar and to socialize with other people in virtual environments. The avatar can be piloted on a smartphone or, if you wear a VRH, using a game controller.
**Results**

3 patients have used the vTime application during the wound closure. This group consisted of 2 men and 1 woman, with a mean age of 54 years. Only one participant had previous VR experience. Before the surgery, all the patients were trained without any issues.

They used the account opened by the department of neurosurgery to preserve anonymity, and a standard avatar. They interacted with an avatar piloted by a neuropsychologist, also wearing a VRH, under the control of a physician, participating to the meeting and controlling the scene on a smartphone connected to the application—which allows to keep an eye on the operation (multimedia appendix 1: [13]). The mean time of connection and interaction was 10 minutes.

During the experiences, the patient had a passive role, viewing the neuropsychologist avatar and reproducing and commenting on his gestures, or a more active role, controlling his own avatar with a game controller in their hands (multimedia appendix 2: [14]).

Despite uncomfortable conditions of the awake surgery environment and as for other tasks completed with the VRH, no patient experienced, eye strain, nausea, or any sign of “virtual reality disease”. No seizures occurred while the patients looked at the VR experience.
Discussion

Principal Results

As described previously, social cognition includes non-verbal language, empathy and the ToM. These functions are explored at the bed side by complex tasks batteries including story movie, comic strip or interactive games presentation depicting a short story. These tasks need time to be performed, meaning they are not compatible with the brain mapping conditions (DES length inferior to 4 sec, fast response, no ambiguity in the answer).

VR that allows interacting with an avatar is now a common approach in cognitive neurosciences[15]. There is consistent evidence that avatars are perceived in a similar manner to real human beings and could be used to explore the complex processes of non-verbal language, empathy and ToM[16]. In VR, the social interactions are governed by the same social norms as social interactions in the real world, (for example social norms related to gender, interpersonal distance, eye gaze)[17].

VR can be utilized to imitate complex social situations, even for the patient having an awake craniotomy. The potential of VR lies in its increased ecological validity, as compared to screen-based studies. Rather than being a passive observer of stimuli on a computer screen, participants in a virtual environment themselves become part of the depicted scene. Whereas an increase in ecological validity often results in a decrease in experimental control, immersive VR has the potential to combine the naturalness of everyday interaction with a degree of experimental control required by a brain mapping procedure.

Instead of developing a specific application to test and map social cognition during an awake brain surgery, we decided to test the potential of available VR social networks. Several VR social platforms are already available, such as vTime[12], Oculus, Facebook Spaces, PLUTOVR and AltspaceVR. Interestingly, these platforms take different approaches to conveying nonverbal language.: arms, hands, head, and mouth movement and gaze.
For our trial, we chose the Samsung VR option. It is a low-cost, high-quality, customizable wireless device, with a pad control and a game controller if necessary. The VR social network vTime is compatible with the Samsung VRH[12]. The vTime application allows interaction with several avatars and controlling of their position in different virtual environments. The avatar can point anywhere in the scene and produce gestural expressions such as, OK, Thumbs Up, Clap, Thumbs Down, Blow Kiss etc[12]. It is also possible for the user to touch other avatars or to take control of their personal space.

We demonstrated that it is possible, for a patient having an awake craniotomy to wear a VRH and to interact with an avatar piloted by a neuropsychologist.

Limitations

However, we experienced some difficulties and limitations using vTime[12]. During an awake surgery, the patient is usually lying on their back, or on their side with their head immobilized by a Mayfield skull clamp. The vTime app[12], as with most VR social experiences, is not well adapted for use in this position and cannot make use of the 360 degree view and offers no option to control the orientation of the virtual environment. In our experience, Vtime can only be used for patients lying strictly on their side. Moreover, it is not possible to control facial expression, and eye gaze, which are potent nonverbal language cues.

Conclusions

We showed that it is possible to use a VR social network during an awake craniotomy, and to at least test gesture communication. Progress in VR development is currently promising and some VRH even allow facial expressions to be captured and transferred to a virtual avatar in real time, opening a new level of virtual human interaction. We are convinced that these developments could be applied to further research for awake craniotomy, nonverbal language, empathy and ToM in the near future.
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Conflicts of Interest
“none declared”.

Abbreviations
DES: direct electric stimulation
RCT: randomized controlled trial
ToM: theory of mind
VR: virtual reality
VRH: virtual reality headset

Multimedia Appendix 1: figure
During awake brain surgery, the patient and the neuropsychologist (A) performing a language task. (B) Direct electrical stimulation and mapping of the cortex during the task. (C) and (D) the patient and the neuropsychologist communicating with the VR social network.

Multimedia Appendix 2: video
Video showing interaction between the patients and the neuropsychologist avatar using Vtime[12] in order to test social cognition during awake brain surgery.
References


