Neurotechnology and VR. Compatibility and risks

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Abstract. Over the past century, technology has tightly entered our daily lives, penetrating into all spheres of society. Developing, they are increasingly changing our usual world and lifestyle. One of these technologies is virtual reality systems and neurotechnologies, in connection with which this article is devoted to them. In particular, this work provides information about neurotechnologies and virtual reality. The associated risks arising from the use of these technologies are considered. The principle of interaction between neurogarnitures and virtual reality is given.

1. Introduction
Neurotechnologies are technologies that allow us to understand how the brain works, helping us to read brain activity, to work with various aspects of consciousness. Combining all the achievements of modern science, they allow you to study and heal the brain by visualizing the processes taking place in it.

The most popular use of neurointerfaces in medicine is neurorehabilitation. This is a set of measures aimed at restoring lost motor functions as a result of injuries of the nervous system. According to the ideas of active retraining in order for the restoration of functions to occur successfully and in the shortest possible time, physical rehabilitation must meet the following requirements. First, the patient needs to train in an environment that is as close to real life as possible. Secondly, since learning to perform movements mainly occurs through trial and error, the patient should be able to recognize his mistakes, in order to then successfully correct the execution of the movement.

In other words, the patient is necessarily provided with objective information about the progress and quality of the task. And thirdly, the patient must want to be actively involved in the process. Using traditional methods of physiotherapy, for example, remedial gymnastics, it is not always possible to combine all these prerequisites for active training of the patient in motor skills. Therefore, there is an alternative that, with its unique capabilities to reproduce almost any environment and provide additional feedback signaling errors, has proven to be extremely effective in transferring motor skills training - the use of virtual reality technologies. In this regard, virtual reality with its capabilities to simulate almost any space, to present practically unlimited feedback and highly motivational game tasks is able to fill in the missing components of a successful rehabilitation program [1].

At the moment, there are already computer "games" that allow you to develop the skills of self-regulation (for example, relaxation or concentration). For the most part, these games are provided together with neurogarnitures and related software.

Virtual reality is a "real world" in an "unreal space". Moreover, the concept of "real world" includes not only the reality around us, but also fictional objects and locations. The main thing is that they can be visualized in the digital space.
The user’s vision and hearing become “disconnected from the real world” when immersed in a virtual environment through a helmet, which, combined with the ability to move, contributes to a great involvement in the programmed environment, as can be seen from the figure 1, that shows a photo of a person using a virtual reality system.

Figure 1. Photo of a person in virtual helmet.

The field of application of this technology is very wide: whether it is marketing or architecture, medicine or education, virtual reality systems everywhere will be able to contribute [2]. One of the most striking examples of such a contribution can be the ability to equalize the capabilities of people with disabilities with ordinary users—the virtual world does not care about human flaws, it gives a chance to neutralize this with a variety of technical and software solutions. Starting from a modified control method, ending with a specially designed application. That is why anyone will be able to simulate control of a ship (sea or space), realizing their dream, without looking back at any restrictions (besides, who knows, perhaps one day humanity will be able to link the control of real objects through a virtual environment), empowering people with disabilities.

2. Neurotechnology and virtual reality

One of the new ways of using neurogarnitures in a virtual environment can be simulators for teaching self-regulation skills, in which the principle of biofeedback will be applied. In more detail, one of the physiological parameters (heart rate, galvanic skin response, encephalography, thoracic / diaphragmatic respiration, etc.) recorded using wearable sensors should be displayed in the virtual environment in the form of graphic information. The user, interacting with the virtual environment, based on the information received, can indirectly influence his state. Such interaction will significantly speed up the process of mastering the skills being trained due to greater involvement through the virtual environment. The use of a virtual gaming environment in biofeedback technology may become an impetus for the widespread adoption of neurotechnology. Such devices are already being developed for the purpose of
rehabilitation after stroke, treatment of Parkinson's disease, multiple sclerosis. Including similar developments are carried out by Russian companies (ReviVR, iBrain).

The combination of virtual reality and neurotechnology will not only get rid of crutches in the form of controllers (giving us the opportunity to control the digital world through thoughts), but will also be able, in the future, to simulate sensations for other organs of perception.

Speaking of technologies, one cannot but touch upon the topic of markets, since they reflect the demand and influence the prospects for the development of technologies.

A general idea of the virtual reality market can be given by the graph shown in figure 2. So, according to experts from CitiGroup [3], the market development trend is such that by 2035 its volume will amount to $2.16 trillion. Considering that today these technologies are becoming more accessible and widespread, such growth is expected. Moreover, it can be noted that over time, a large part of the market will be made up of such commercial services as music concerts and so on. This phenomenon is due to the fact that virtual reality allows you to achieve greater immersion, which, in turn, brings the most powerful emotional experiences.

![Figure 2. Information about the virtual and augmented reality market.](image)

The situation in the neurotechnology market can be seen in the figure 3 below. The neurotechnology market is actively developing today. So, according to the data provided on the website of the analytical center under the government of the Russian Federation [4], it can be seen that in the near future this market will develop and grow, which, in turn, will affect the development of related areas and industries.

But do not forget that a person, having created a technology, falls under its influence. A vicious circle arises, where technologies and people mutually influence each other. The simplest example is the Internet, which has become an indispensable resource for human society. Fast exchange of information and relatively easy access to topics of interest to a person – look like an indisputable plus, however, the reality is such that behind it are hidden a number of significant disadvantages generated by the endless flow of information. To begin with, a person is not multitasking. No matter how stated the opposite, but, with rare exceptions, people can perform as efficiently as possible only one task. With an increase in their number, concentration of attention decreases, which leads to a decrease in efficiency.

Moreover, information needs time for assimilation, which occurs during rest (examples of such rest can be sleep, meditation). If a person receives information by skipping the stage with "assimilation", then the amount of information he assimilates (and how long he remembers it) is significantly reduced. All of the above leads to the fact that a person is reduced: the ability to concentrate attention on one object (since we strive to pay attention to everything at once); depth of understanding of information; the ability to rethink (we do not stop receiving all the new information without paying sufficient attention to what has already been received) - new impressions are quickly forgotten [5].
In addition, we become addicted to information. Entertainment stories and “pictures” activate the center of pleasure in our brain, such an effect on it is exerted by such types of passive pleasure as delicious food, alcohol, drugs or sex [5]. The readily available pleasure makes us constantly receive a new “dose”, while our brain has not processed the previous one and, as a result, the information does not linger in our memory for a long time.

Now, given the example of the Internet, you can look at virtual reality from a slightly different angle. Figuratively speaking, virtual reality is an immersive internet. The emotions obtained in it are brighter and sharper than from the use of other devices (due to the greater “realism”). If the level of the virtual world grows, the issue of “virtual migration” may become as acute as the issue of deterioration of human abilities. But, let's be honest, the problem in these matters (when a person is looking for a better and brighter world) does not lie in technology. However, technology can help us prevent most of the negative effects. In particular, in the matter of virtual reality, neurotechnologies are able to play not only the role of expanding the functionality, but also as a limiter that protects the user's health.

Capable of monitoring the state of a person, they can act as a built-in limiter – if the indicators taken from the user do not correspond to normal values, the system will be able to forcibly end the session and, if necessary, will call for help. But these are technologies of “tomorrow”, and in order to achieve them, you need to start with small steps.

In connection with the above, the first "small step" for us is the development of a software module capable of capturing data on human brain activity and transferring them to the game engine. The expected result is the execution of pre-programmed actions in virtual reality, based on the data of brain activity taken from the neurointerface.

This module will allow combining two independent devices based on one engine, which will significantly expand the possibilities of using these devices, in particular, it is expected that such an approach, at the current stage, will bring positive results in the field of psychology and rehabilitation.
3. Neurogarnitures

It is most likely that the first neurotechnologies that will interact with the virtual world will be neurogarnitures—devices that allow you to record an EEG, remove a signal of the electrical activity of the brain from the surface of the head and transmit it to a computer or similar device. They are conventionally divided into as follows:

- By field of application (research; consumer)
- By the form of connection (wireless; wired)
- By types of electrodes (dry; wet)
- By registration methods (bipolar; monopolar)

The neurogarinture of the Mind Link helmet located on the user's head is shown in figure 4. Such a helmet is not oversized and is quite suitable for private use by users at home, as can be seen from this figure.

![Figure 4. Photo of a person wearing a neurogarnitures.](image)

In general, they represent the following: a design that allows you to put on a device and sensors (EEG, GND, REF) that read brain impulses. Basically, devices of this type use a TGAM chip from NeuroSky (USA), which allows you to use third-party software based on it. It is important that due to the fact that the position of the electrodes must be clearly exposed, and the size of the user's head is different, the design of the neurogarintures should allow them to freely change the size in reasonable ranges.

Principle of operation: the device is put on the head (an important condition is that the electrodes must touch certain active areas of the brain (depending on the neurogarintures, the number and location of the electrodes on the device may differ)); the computer “sees” the device; the program starts; sensors transmit information to a computer through a connection; the program processes and visualizes the received data.

The main problem with registration is artifacts. In order to reduce the degree of their influence on the registered results, the following are being developed:

- New ways of fixing electrodes
- Electrode modifications
- New methods of signal registration
The main areas of application of neurogarnitures:
- Medicin
- Science
- Sphere of entertainment
- Marketing

Companies engaged in the development of neurogarnitures:
- NeuroSky
- Macrotellect
- Interaxon
- Emotiv
- Cognionics
- gtec.at
- Neuroelectrics
- Mitsar
- AdvancedBrainMonitoring
- OpenBCI

4. The principle of interaction between neurogarnitures and virtual reality

While working on ways to combine the Mind Link neurogarnitures and virtual reality, a module was created that allows them to communicate on the Unreal Engine and Unity.

Description of the data of brain activity sent by the device (neurogarnitures):

Poor signal quality (POOR_SIGNAL Quality) is an unsigned one-byte integer that describes the weakness of the signal measured by the neural interface. It ranges from 0 to 200. Any nonzero value indicates that some kind of noise pollution has been detected. The higher the number, the more noise is detected. The value 200 is of particular importance, in particular, the contacts of the neurointerface do not touch the user's skin.

This value is usually displayed every second and indicates poor results from the most recent measurements. A bad signal can be caused by several reasons. In order of severity, they are:
- The contacts of the sensor, ground or reference are not on the person's head (ie, when no one is wearing the neural interface).
- Poor contact of the sensor, ground or reference contacts with human skin (ie hair is in the way, or the garnitures is not properly worn on the person's head).
- Excessive user movement (ie, excessive head or body movement, garnitures jolting).
- Excessive electrostatic noise from the environment (in some environments, there are strong electrical signals or a build-up of static electricity in the wearer).
- Excessive biometric noise not related to EEG (eg EMG, ECG / ECG, EOG, etc.)

Most typical users who are only interested in using values such as Attention and Meditation should not worry too much about the POOR_SIGNAL Quality value, except that it should be noted that the Attention and Meditation values will not be updated when POOR_SIGNAL is detected. The bad signal quality value is more useful for some applications that need to be more sensitive to noise (for example, some medical or research applications), or applications that need to know immediately when even minor noise is detected.

By default, the output of this data value is enabled. It is usually displayed once a second.

The principle of joint work of a neurogarnitures and virtual reality can be described as follows, is shown in figure 5:
Figure 5. Algorithm for interacting with virtual reality on the Unity engine.

The software product is a local application with a simple logical model represented as a UML class diagram shown in the figure 6.

This module allows interacting with virtual objects (whether it be levitation of an object or other interactions) based on the indicators read from the user.
For a better understanding of the neuromodule operation, let's consider the implementation of game mechanics based on brain data. Suppose we need to implement an increase in a 3D primitive depending on the threshold value of a person's attention level.

In order to interact with objects on the game scene, a mechanism is needed to understand what exactly the user wants to interact with this object. In this case, this will help provide Line Trace if we use the Unreal Engine, or Raycast in the case of the Unity engine – a ray that has origin coordinates (where the ray will be emitted from) and a direction vector (where the ray will be emitted). In this case, the ray will have the coordinates of the head in space as the initial coordinates, and the vector of the direction will be the vector of the direction of the head. Thus, the user will emit a beam in the direction in which he turns his head. If the neurohelmet was successfully connected, the module will read the data from the user's brain. Then, after the collision of the ray with the object, we check the value of the person's attention level. If this value exceeds the predetermined attention threshold, then the function is called that implements the increase in the size of the primitive, otherwise we read the attention value again while the ray collides with this object.

The general principle of interaction of the main elements of the system and mathematical models of the system based on a virtual reality helmet and a helmet of neurotechnologies can be illustrated by figure 7. The interaction between all elements (including the user) occurs in a closed loop: from the computer to the virtual reality helmet, then from the VR helmet to the user, then from the user, the read data is transmitted through the neural headset to the computer, from where it is transmitted again to the VR helmet.

![Diagram of interactions](image)

**Figure 7. Diagram of interactions.**

Briefly, the result of each step can be summarized as follows:

- connection establishment – in case of successful connection, the function should return 0 (code of successful completion of work);
- incorrectly passed parameter when establishing a connection - in case of such a connection, the function must return an error code;
- obtaining data of brain activity – non-negative values of a person's concentration level should be displayed in the logs;
- incorrectly transmitted parameter when receiving data of brain activity – a negative number should be displayed in the logs, indicating that such a value is not stored in memory;
- checking memory clearing when the connection with the device is broken – initially, non-negative values of the level of human brain activity should be displayed in the logs. After disconnecting the neural interface from the PC in 12 s. a complete break in the connection with the device should occur, and the brain activity data left over from the previous connection should be deleted, and a negative value should be displayed in the game logs;
• checking that the connection is maintained when switching between locations – at the first and second locations, non-negative values of the level of human brain activity should be displayed without losing the connection with the device;
• using module functions in different Blueprints – as a result of these steps, the behavior of the functions should be as follows:
  1. If the connection is successful, the GetBrainDataAbout() function should return non-negative values of the level of human brain activity, and after disconnecting the neurointerface, negative values.
  2. The isConnected() function should return true when the neural interface is connected, and false when it is disconnected.
• interaction with objects on the game scene based on brain activity data – as a result of a successful connection, the GetBrainDataAbout() function should return non-negative values of the brain activity level, during the processing of which the implemented mechanics should be performed;
• closing a connection before establishing a connection – as a result of these steps, the program should run without critical errors and not throw exceptions. As a result, a successful connection to the device should be completed;
• re-establishment of connection with the device – as a result of these steps, both functions should return 0 (code of successful completion of work);
• checking the operation of the module with the neural interface removed - before removing the neural interface from the head, the game logs should display non-negative values of the level of human brain activity. After removing the neuro-helmet, zero should be displayed in the game logs, which indicates that the helmet does not detect any electrical signals. After putting the neural interface back on, the game logs should display data on the level of brain activity without losing the connection with the device;
• checking the connection to the device – as a result of performing these steps, the isConnected() function should return true for the first time as a result of a successful connection, and the second time should return false, since the function of closing the connection CloseConnection() was called.

An example of the results obtained by implementing these steps in practice is shown in figure 8 and 9. Figure 8 illustrates a 3D object before interacting with it. Figure 9 illustrates the object after manipulation, using a neural headset without the use of additional devices (mouse, keyboard, etc.).
5. Conclusion
The efficiency of the module was confirmed and corresponded to the expected results - the execution of pre-programmed actions in virtual reality, based on the data of brain activity taken from the neurointerface. Considering all of the above, its use in conjunction with virtual reality will increase the level of user engagement, which will have an extremely favorable effect on the consequences of such a symbiosis.

Summing up, we can conclude that the use of a combination of virtual reality technologies and neurotechnologies can become one of the significant steps in achieving new ways of interacting with the virtual world. By removing indicators from neurodevices that monitor the user's state and creating a database, we can carry out mathematical modeling, after which, having set the necessary parameters and settings, we can transfer the received data into the virtual world, which will allow us to move to a new level of interaction with the digital space.

In addition, despite the possible risks, these technologies themselves are not a threat, therefore the level of their safety will be regulated only by humanity and its ability to assess the possible consequences.

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