# [Working Title] Using a neural interface for interaction in virtual reality

**an HCI study**

## Masters Thesis

**To obtain the academic degree M.Sc.**


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# Contents

# Abstract

Modern technology evolved to pick up the eletric signals emitted from the human brain in order to generate user input to eletronic equipment. This study aims to evaluate a demo use-case by using a neural interface from nextmind to control user interactions in Virtual Reality.

# 1 Introduction

In recent years significant progress has been made on the development of interfaces which relies on direct interaction with the brain itself. find some sources The latest popular example is *Neuralink* with their monkey learning to play the game *Pong* only by using its brain (Neuralink (2021)). However there are more examples of a working interface: Do som research here. These interfaces are generally called *Brain-Computer-Interface* or *BCI* in short. The general working principle is sensing the electrical signals of the brain and use this information to generate any kind of arbitrary output find source. In certain use cases like motoric reactions to visual cues, this could potentially reduce total reaction time. This study aims to examine a potential use case with a device which is readily available to consumers.

## 1.1 Brain-Computer-Interfaces

In this section a general overview of the working principle of these interfaces will be provided. Since this study is aimed at computer science and HCI[1], the neuroscience and medical domain will be only covered very briefly.

First studies began by Vidal (1973), who investigated the possibility to use EEG[2] waves, which were first recorded by Berger (1929), as a way to create a direct interaction between a machine and a human brain.

There are three types of BCIs: invasive, partially invasive and non invasive. This depicts the degree of intrusion into the skull and brain tissue. *Invasive* BCIs are electrodes, which are implanted directly into or onto the grey matter of the brain. This can cause long term issues like scars and also degraded singal strength according to Abdulkader et al. (2015). Partially invasive BCI however are although located within the skull not in direct contact with the grey matter. Non-Invasive BCI are only placed on the head without intrusion of any tissue. Due to the direct contact, invasive BCI provide the best resolution of the measured signals. Non-invasive BCI in comparison suffer from signal degradation and deformation of the cranial bone tissue. Therefore partially invasive BCI are a compromise between good signal strength and the risk of medical conditions.

The way these interfaces work is based on the same principle: A human brain emits electrical signals, which can be picked up. According to Vidal (1973), they can be described as follows:

[1] Human Computer Interaction

[2] Electroencephalogram

*"Embedded in this sustained "spontaneous" or "ongoing" electrical activity, short, distinctive (0.5-2 sec) waveforms can be found that are evoked, for instance, when a brief sensory message (stimulus) such as a brief illumination of the visual field or a tap on the forearm is received by the subject."*

Based on the origin within the brain, these can be correlated to certain stimuli, mental and emotional states (Jardim-Gonçalves (2018)) and according to Waldert (2016) been used to drive *an external effector or affecting internal body parts and functions.* The external effector is the use case which is being examined in this study.

Without a BCI, interaction with a computer requires some physical interaction with devices such as keyboards, mouses or gestures on a touch screen. There are mainly two different reasons, why these devices are a constraint to speed and efficiency of HCI. The first reason is a limitation on interaction speed: Although there is no definitive concensus about the speed of thinking, the majority of people would agree, that typing along in the same speed as the thinking process is usually impossible - except for rare individuals who devoted a significant time practicing. Secondly: in applications such as games, where reaction time and accuracy is the fundamental element for success or failure, an interaction based on motoric interaction with a physical pointing device has some significant drawbacks like limited accuracy, if the whole chain of wrist movement in conjunction with a mouse is under scrutiny.

If a BCI was to replace these types interaction, these constraints could potentially be alleviated and interaction based on physical interaction rendered obsolete.

## 1.2 Working principle

Before any deeper considerations in regard to the general scope of this study can be made, it is important to understand the working principle of the BCI, which will be used. Although the vendor of the BCI in question does not disclose any details of the inner workings itself, it is safe to assume that the underlying technique used is the so called *Visually Evoked Potential* - VEP in short. Sokol (1976) provides detailed inside into the topic from a neuroscientific point of view. The general principle however is that any visual stimuli cause a certain pattern of waves within the visual cortex of the brain. These patterns can be used to evaluate if a certain pattern is being seen *and* in fokus of the person. This is being done by subsequently feeding the sensor data through a trained neural network. The objects, which are being seen by the person, have been labeled *neurotags* (NextMind (23/11/2020)) from the vendor of the BCI. These neurotags can provide two different readouts: If it is triggered (i.E. *seen*) and the confidence, which depicts the level of *focus* of the user on the neurotag (NextMind (18/11/2020)).

The physical layout of the sensor is show at figure 1.1. It has 18 eletrodes, which are arragend in pairs to cover the area, where the visual cortex is located at on the back of the cranium. It is battery driven and communicates via the Bluetooth LowEnergy protocol.

**Figure 1.1:** Physical layout of the sensor

## 1.3 Related work

Non-Invasive BCI based on VEP has been around for while now and therefore a significant number of studies has been carried out to further examine ... Continue here...

- State of research
- Applications in the HCI domain
- other...

This chapter is very much WIP

## 1.4 Use case "Neural Interface in VR"

Before any use case can be conceived, it has to be determined what kind of interaction this interface allows. Section 1.1 covered briefly the concept of input taxonomies to elaborate optimization potentials with BCIs. According to Find some source an input taxonomy depicts the DOF[3] and the granularity and magnitudes in regard to the interface which this interface offers.

[3]Dimensions Of Freedom

**Figure 1.2:** Taxonomy of the nextmind BCI. Todo: Create taxo schema

Figure 1.2 shows the input taxonomy of the BCI in question. It is derived from the API[4] endpoints which the the SDK[5] of the sensor offers: NextMind (18/11/2020) . The only two *tracking resuls* are *hit* and *confidence*. Where hit is a two state interaction: the neurotag is being seen by the user and subsequently recognized by the sensor and its backend or it is not. The confidence property depicts the attention which the user is paying to the *neurotag*. This is a continuous decimal value between 0 and 1. The fact that these types of interaction are based on neural activity raises the question if a pure mapping of continuous and discrete input modalities to established interfaces would be beneficial to the user experience. Under the reasonable assumption that without any training the metric *focus* can only be deliberately controlled on a very coarse level, the necessary sensitiveness required for modern GUIs can not be achieved with this particular sensor. The remaining two state property, which can be utilized to select or deselect certain objects also only allows for limited interaction. However, these neurotags can be placed in arbitrary places. Although a *toggle*-like behavior is not mentioned explicitly, it might be possible to de-select any activated neurotag when the *focus* property falls under a certain value.

Based on the previous reasoning, the following questions can be raised in regard to the feasibility of any interface which could potententially be conceived with this technology:

- How fast is the perceived and measured reaction time of these neurotags?

[4] Application Programming Interface
[5] Software Development Kit

- What is the minimum size the neurotags have to have in order to be recognizable?
- Is the interface usable for brains of all ages or do gerontological effects have an effect on usability?
- Do certain medical conditions (i.e. attentiveness disorder) have an impact on the usability?
- How fast can a user switch between neurotags?
- Is a BCI controlled GUI intuitive to use?
- Does a personal affinity to technology have an influence on the perceived difficulty of interaction?

These questions can be clustered into two groups: *neurological* and *interaction*. Although these considerations open up a vast space of potential cases. Therefore the priority is to examine wheter these interfaces are generally usable by the majority of users and if these interfaces are intuitive to use.

## 1.5 Hypothesis

The considerations in the previous section leads to these two hypothesis:

*"Age does not have a detrimental effect on the ability to use a non-invasive BCI based on VEP technology."*

and

*"VEP BCI operated GUIs are intuitive to use."*

# 2 Technological challenges

Due to being non-invasive there must exist certain drawbacks with this technology. I want to examine the shortcomings and possible ways to overcome these. A valuable resource of information might be nextminds homepage.

## 2.1 Resolution of the Interface

- definition of the resolution parameter
- input taxonomy diagram
- how to examine with survey

## 2.2 Constraints

As far as I understood, the interface allows for four different interaction goals. It would be interesting to see, which kinds of interaction are possible.

- Interaction objects
- interaction types in regard to input taxonomy
- evaluation in user survey

# 3 Survey Structure and layout

## 3.1 Considerations

- Which topics do I want to evaluate in detail
- what are my tools
- Who is my audience
- how to I operationalize the values for context
- What are my performance indicators

## 3.2 Survey structure

Based on the findings, I want to define the survey in this section.

- item 1
- ...

## 3.3 Survey

How is the survey carried out. This depends largely on the outcome of section survey structure.

- item 1
- ...

# 4 Survey results

Once the study has been structured and carried out, I can write down the results.

# 5 Findings

This section also depends on the outcomes in context to the resarch question.

# 6 Conclusion

## 6.1 Results

Summarizing the results and findings of the study briefly.

## 6.2 Future Work

Based on the findings and new devices on the horizon, this should give a brief outlook on how to continue this research.

# 7 Acknowledgements

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# A Material

## A.1 Surveys, Protocols, etc.

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I hereby confirm that this thesis is my own work and that I have not sought or used inadmissible help of third parties to produce this work and that I have clearly referenced all sources used in this thesis. I have fully referenced and used inverted commas for all text directly or indirectly quoted from a source.

Place and date | Julius Neudecker