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Systems Neuroscience & Neurotechnology Unit

Closed Loop Virtual Reality for the Treatment of Phobias

Bachelor Thesis

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Declaration

I hereby declare that I have authored this work independently, that I have not used other than the declared sources and resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources. This work has neither been submitted to any audit institution nor been published in its current form.

Saarbrücken, February 21, 2018

Dominik Limbach

Abstract

we want to find out if it is possible to design a fully automatic therapy system using vr and psycho physiological measurement. therefor we will test our virtual environment with a random group of subjects and measure ecg and gsr the goal of the conducted experiment is to show that our virtual reality is capable ob causing fear this will be done by evaluating the measured bio data

furthermore our virtual can be controlled by a therapist the therapist will be able to exercise control through a matlab program provided with real time visual data the therapist will be a substitute for the AI which will later be controlling the vr respectively to the measured data

the vr and the related pc will feed visual input to the subject this input is processed by the subject and he gives output information in the form of gsr and heart rate serving as input for our third system, the therapist (visual presentation of processed data) therapist can control vr —loop closed

Zusammenfassung

translation of abstract

Acknowledgments

Contents

1 Introduction

Virtual reality combines real-time computer graphics, body-tracking devices and high-resolution visual displays to create a computer-generated virtual environment. With their ability to immerse the user into a virtual mirror of the real world, virtual environments are a powerful tool in clinical application, especially in the treatment of phobias (Riva, 2003).

Studies have shown anxiety disorders to be the most prevalent mental disorders (Kessler et al., 2005). Many consider exposure therapy the most effective form of treatment for specific phobias (DeRubeis and Crits-Cristoph,1998). However that may be, considering the nature of certain phobias such as fear of heights, exposure therapy involves a genuine risk of injury. Performing therapy in a virtual environment therefore can be a promising alternative to the conventional in-vivo exposure.

The efficacy of virtual reality exposure therapy (VRET) has already been demonstrated in the past. A study conducted on acrophobia compared two groups of student subjects. The first group received a graded VRET. Students of the second group were added to a waiting-list as a control group. Results showed that VRET is more effective than no treatment (Rothbaum et al.,1995). VRET was also found to be as effective as exposure in-vivo in a more recent work by Emmelkamp et al. (2002).

In addition to this using a virtual reality system can have a number of advantages over in-vivo exposure. First and foremost being the ability to conduct therapy inside a controlled and secure environment like a therapist's office. This also implies therapy being less time consuming and provides considerable financial benefits (Cavanagh and Shapiro, 2004). The possibility of having therapy in a more private scenario also could lead to it becoming a more attractive choice for patients, that are too anxious or fear public embarrassment. A recent study exploring the acceptability of virtual reality exposure and in-vivo exposure in subjects suffering from specific phobias supports this hypothesis. Seventy-six percent chose virtual reality over in-vivo exposure. In addition to this the refusal rate of 3% for virtual reality exposure was substantially lower than 27% for in-vivo exposure (Garcia-Palacios et al., 2007). Further epidemiological studies show a lifetime prevalence of 28.5% for vHI and 6.4% for acrophobia alone and only 11% of susceptible people consulting a doctor (Huppert et al., 2013; Kapfhammer et al.,2015).

These results suggest that virtual reality exposure could help increase the number of people who seek therapy for phobias and therefore needs to be established in everyday clinical work.

In recent years there has been a lot of research on virtual reality treatment for different phobias trying just that.

For example a controlled study by Rothbaum et al. on aerophobia (2000) as well as a open clinical trial post-traumatic stress disorder (2001) and a study on agoraphobia (Meyerbröker et al.,2011), all of which yielded positive results. There also have been studies on ways to control the virtual reality. In a pilot study, Levy et al. (2015) explored the possibility of a remote-controlled virtual reality. After a trial session in a neutral virtual environment the patients received a total of six therapy sessions. The first three sessions were remote-controlled virtual reality exposure therapy (e-VRET) followed by three sessions in the presence of a therapist (p-VRET). E-VRET sessions were conducted without any contact to the hospital staff. The study showed that e-VRET not only is possible but produces results equal to p-VRET. Assessing the mental state of a patient is essential for the success of the therapy. A task which usually falls to the hands of the therapist and in most cases relies on a verbal communication between both parties. Past studies have shown a strong psychophysiological arousal in in-vivo exposure for different specific phobias (Nesse et al.,1985; Alpers and Sell,2007). In a more recent work Diemer et al. (2015) also confirmed physiological arousal in subjects executing a virtual height challenge. The study examined phobics and healthy controls in terms of subjective and physiological fear reactions resulting in a significant increase of subjective fear, heart rate and skin conductance level. To prove this hypothesis, we designed a virtual environment for the treatment of acrophobia that is sufficiently adaptable to various degrees of acrophobia. We will show the effectiveness of our system based on a subjective rating as well as heart rate and skin conductance measurements. Further we will deploy our virtual environment in a closed loop virtual reality system, featuring multiple control units. We will conduct a experiment simulating the effect of real-time physiology based decision making by using a remote-controlled virtual reality.

1.1 Theoretical Background

In this chapter, we will give a brief introduction to the field of anxiety disorders, especially specific phobias and the associated therapy concept, which is exposure therapy. The first part will contain fundamentals on phobias, exposure therapy and the concept of fear. Furthermore we will elaborate on the psychophysiological influences of stress and anxiety on certain parts of the human body and functions as well as methods of determination in physiological measurement. The second part will recapitulate recent approaches on virtual reality exposure therapy and analyze existing problems.

1.1.1 Acrophobia

1.1.2 Stress

1.1.3 Electrodermal Activity

Electrodermal activity (EDA) is a collective term for all electrical phenomena in the skin, which was first introduced by Johnson and Lubin (1966). This includes active and passive electrical properties, caused by skin functions and skin structure as well as the appendages of the skin.The skin appendages are structures formed by skin-derived cells such as hair, nails, sebaceous glands and sweat glands. EDA is one of the most commonly used response systems in psychophysiological research. This is due to its relative ease of measurement and its sensitivity to psychophysiological states and processes. The following section will provide a brief overview of EDA, ranging from physical and psychological context to recording and quantification methods.

Anatomical basis

This section will elaborate on the anatomical aspects of the human skin and will cover all the parts and appendages, that are needed to understand the principles of EDA. The skin or cutis is the biggest organ of the human body and inherits many different functions, which are essential for survival. It primarily acts as a selective barrier, preventing the entry of foreign matter and enables the passage of materials from the bloodstream to the exterior of the body. Other than protection, it is involved in thermoregulation, cutaneous circulation and immunologic protection. The anatomical structure of the skin is similar in most regions of the body. Although, specialized regions of skin, such as the palms and soles may be resembling in structure, they possess modified characteristics.

The human skin is composed of two clearly distinguishable layers, the epidermis that serves as a protective barrier and the dermis that provides nutrition. The cutaneous structures are vertically arranged and located on top of the subcutaneous tissue. Figure 1.1 shows a representation of each of the layers and their general spatial configuration among themselves.

The epidermis, on its own, can be divided into five different layers and lies on the surface of the skin. It consists of epithelial tissue, which is built in the lowest layer, the stratum germinativum. The main part of the produced cells are keratinocytes, which are able to store keratin and therefore become horny over time. The keratinocytes migrate to the surface of the skin, causing the epidermis to become more horny when approaching the surface. The outer layer is called the stratum corneum, originating from the fully

Cutis (skin)	Epidermis	Stratum corneum	upper zone middle zone lower zone
		Stratum lucidum Stratum granulosum (granular layer)	Stratum intermedium
		Stratum spinosum (prickle cell layer) Stratum germinativum (basal layer)	Stratum Malpighii
	Dermis (cutis vera = true skin)	Stratum papillare (papillary layer) Stratum reticulare (reticular layer)	
Subcutis (hypodermis)			

Figure 1.1: The Layers of the skin.The zonal layering is not so distinct in every skin region. Note that the stratum lucidum is only clearly recognizable on the palmar and plantar skin areas.[**?**]

keratinized state of its cells. On their way to the surface the keratinocytes undergo a number of specific changes in form and areal distribution, which in part are used to define the different epidermal layers. Also the cells become less tightly packed, compared to the deeper layers, causing the epidermis to become dryer towards the surface. A fact that greatly influences the electrical properties of the epidermis and therefore the electrodermal activity. The stratum corneum is especially thick in the palmar and plantar regions of the body. Reaching a thickness of approximately 1 mm, it is almost 20 times thicker than its overall average of 50 μm.
The dermis, which is also referred to as the corium, lies directly beneath the epidermis. Although it is much thicker than the epidermis it is only composed of two different dermal layers, the stratum papillare and the stratum reticulare, which are distinguishable by their density and the arrangement of their collagen fibers. The epidermal dermal junction, which is the transition area between the epidermis and dermis, resembles interlocking hands and is formed by a basal-membrane zone (Boucsein, 2013). The dermal layer, closest to the epidermis is called the papillary stratum. Other than the capillary net of arterial and venous blood vessels, it contains receptor organs as well as melanocytes and free collagen cells. The second dermal layer, which lies on top of the subcutaneous tissue, is called the reticular stratum. It wears this name because of its texture. Formed of strong collagenous fibers, reticular stratum is highly resistant to rupture, granting the dermis is leathery impression.

The subcutis, or hypodermis, is located beneath the dermis and is composed of loose connective tissue. It serves as a connection between the skin and the connective tissue of the muscles, allowing for good horizontal mobility of the skin. The subcutis also serves as a thermal and mechanical insulation layer, due to its ability to store fat. In addition to this it, contains nerves and vessels, which supply the skin with nutrition and information, as well as the hair follicles and secretory part of the glands.

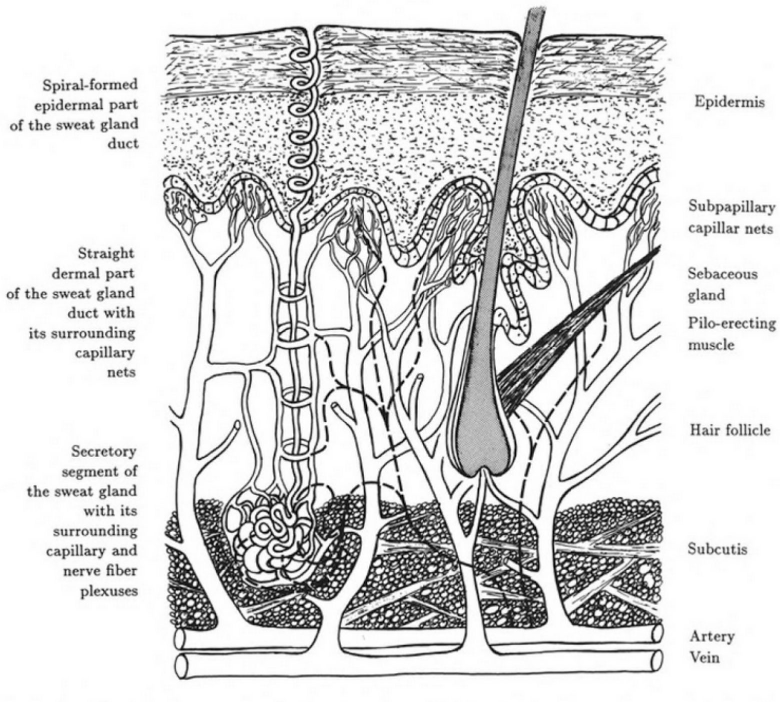

Figure 1.2: A artificial cross-section of the skin. It combines a sweat gland in ridged skin (left) and a hair together with a sebacous gland in polygonal skin (right).[**?**]

The figure 1.4 shows an example of a typical profile of glabrous (hairless) skin. This specific form of skin can be found on the palms of the hands and the soles of the feet. Areas, both of which, are frequently mechanically stressed and differ greatly from the rest of the body.

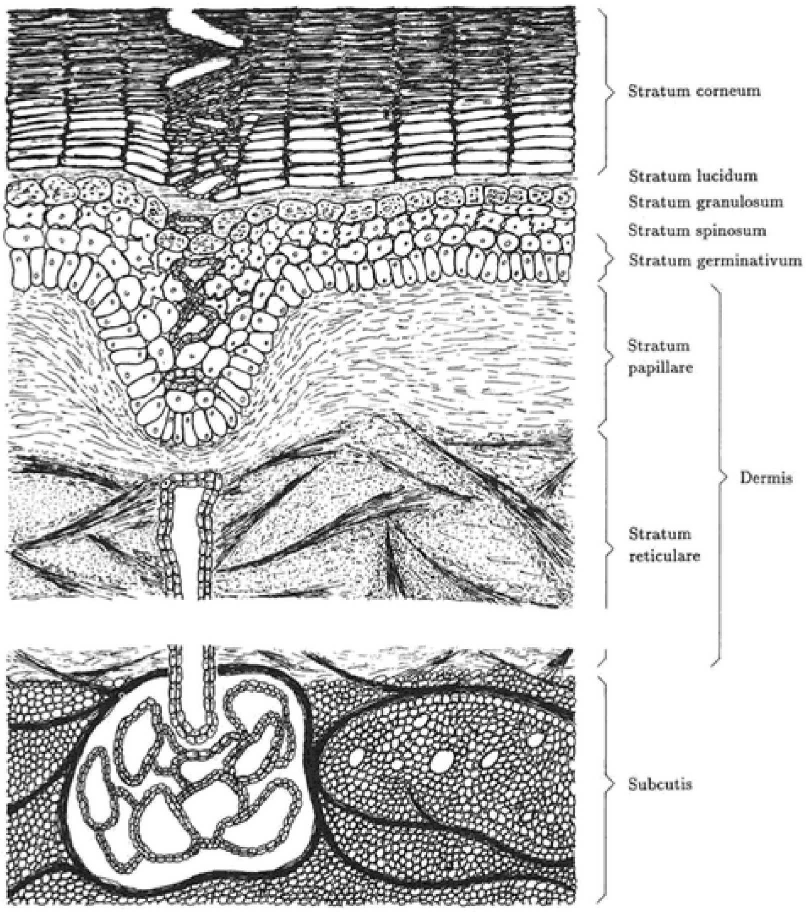

Figure 1.3: A cross-section of the layered construction of the glabrous human skin. An eccrine[?]

1.1.4 Exposure Therapy

1.2 General

1.2.1 State of the Art

1.2.2 Recent Advances in Research

1.3 Problem Analysis and Goals

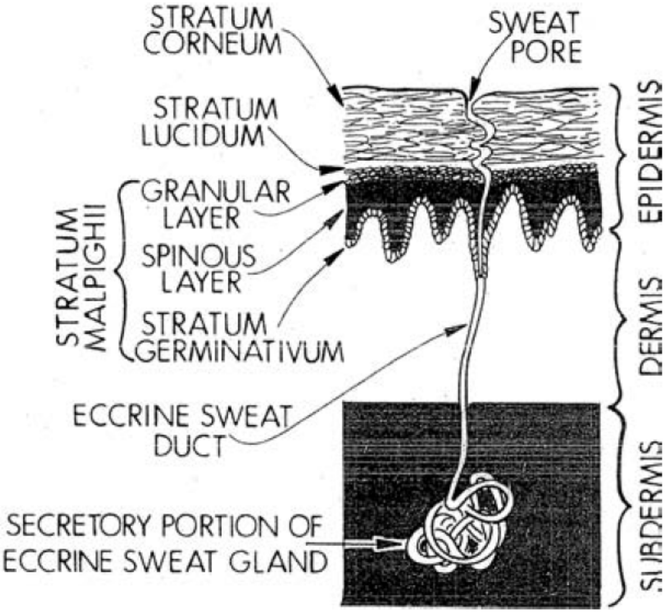

Figure 1.4: Anatomy of the eccrine sweat gland in various layers of glabrous skin.(Adapted from Hassett, 1978)[1]

2 Materials and Methods

2.1 Materials

mention the SNNU and the lab where the study takes place

2.1.1 Setup

- description of the therapy setup
- graphic 1, shows a patient inside the defined treatment area, wearing VR-Headset, the lighthouse system, eeg and gsr sensors, connection to the pc controlled by the physician

2.1.2 Procedure(Paradigm)

- how many subjects did participate?
- which tasks did the patients fullfill? (cross the bridge etc.)
- duration of the experiment

- description of the virtual environment, the procedure (baseline measurement,VRET in detail)
- pictures that show the VE in it's starting state as well as it's therapy state (descended floor)
- description of how the VR is controlled by the user(which parameters can be influenced)

2.2 Methods

- main objective is the measurement of gsr during the therapy and the evaluation of the gsr data concerning the stress of the patient during the therapy
- how is the gsr information processed and evaluated?

how is it presented to the user?
- description of how the VR is controlled by the user(which parameters can be influenced)
- graphic of control chain

3 Results

4 Discussion

5 Conclusions and Future Work

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Bibliography

[1] J.T. Cacioppo, L.G. Tassinary, and G.G Berntson. *Handbook of Psychophysiology*. Cambridge University Press, 2007.