DEVELOPMENT OF A BCI SUPPORTED MOBILE
RESPONSE INHIBITION TRAINING FOR
SYMPTOM RELIEF IN OCD

A Project
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by

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DEVELOPMENT OF A BCI SUPPORTED, MOBILE RESPONSE INHIBITION TRAINING FOR SYMPTOM RELIEF IN OCD

A Project

by

Linda-Marie Weber

Summer 2015

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ABSTRACT

DEVELOPMENT OF A BCI SUPPORTED INHIBITORY CONTROL TRAINING
FOR SYMPTOM RELIEF IN OCD

By

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Master of Arts in Interdisciplinary Studies:
International Cognitive Visualization
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Obsessive-compulsive disorder (OCD) is with a prevalence of 2-3% one of the most common psychological disorders. People, however, generally struggle up to ten years before seeking treatment and prominent treatment methods have high dropout rates. As for every illness, early intervention is key, but until today there has been no real practical solution for self-help that is enjoyable enough to encourage people to continue with their treatment. Based on these data, we developed ShmutzCastle, a therapeutic neurogame targeted at patients with OCD, specifically those who suffer from cleaning compulsions and contamination obsessions. The aim of this project was to build a mobile game that trains OCD patients in their ability to better resist cleaning impulses, to better stop compulsive cleaning behavior, and to overcome contamination fear. The game
incorporates evidence-based interventions including inhibitory control training and systematic desensitization, and uses cutting edge brain-computer interface (BCI) technology to produce an immersive game through which OCD patients learn to master obsessions and compulsion.
CHAPTER I

INTRODUCTION

Purpose and Scope of the Project

The aim of this project was to develop a therapeutic mobile game targeted at patients who suffer from obsessive-compulsive disorder (OCD), specifically those who report cleaning compulsions and contamination fear/germ phobia. OCD is an anxiety disorder characterized by obsessive thoughts and compulsive actions, such as cleaning, checking, counting, or hoarding (Mataix-Cols, Rosario, & Leckman, 2005; Mataix-Cols, Wooderson, & Lawrence, 2004). Individuals who suffer from OCD become trapped in a pattern of repetitive thoughts and behaviors that are senseless and distressing but extremely difficult to overcome (Abramowitz & Jacoby, 2014; Foa & Kozak, 1995). The aim of this project is to build a mobile app that strengthens patients’ ability to better resist cleaning impulses, to better stop compulsive cleaning behavior, and to overcome contamination fear.

A possible way to do so is by providing an opportunity to practice inhibition control on stimuli (i.e. a possibly contaminated doorknob) that would normally trigger compulsive actions (i.e. immediately washing hands), within a game environment. Over time and practice, users will be able to better inhibit their responses to cleaning urges.
A possible way to overcome contamination fear is by confronting patients with dirty environments and asking them to stay calm. In order to measure a patient’s change in emotional stress, we included a Neurofeedback component in the mobile app. This was done by connecting the game with a headset that measures electroencephalographic (EEG) brain activity. For the purpose of this project, we chose a mobile and user-friendly brain-computer interface (BCI) device called ‘Neurosky Mindwave Mobile’. It records EEG signals in real time and communicates with a mobile phone via Bluetooth. With the help of algorithms provided by Neurosky, the EEG signal will be transformed into an emotional state indicating a user’s mental relaxation level. This signal will be used as an input parameter for game play. Hereby, it is important to mention that the brain measurements will only be used in the game parts that target patients’ contamination fear.

The reason why we created a game is that skills trainings like ours can become very boring and mundane, whereas exposure to dirty environments might be too overwhelming for patients. Since patients should use the app independently without being instructed to intrinsic motivation is very important. The final game we created is called *ShmutzCastle*. The game plays in a little town called Cerebrum, which has been invaded by *Repeticia* and *Obsess*. The player’s task is to bring back peace to the town by making friends with the citizens, who look like germs.

In the first two chapters, we will review literature to each component and discuss why we chose each element of the system. In the third chapter, we will describe how the final system works.
Significance of the Project

OCD affects around 40 million people in the US, of which three million fall in the clinical spectrum. Even though obsessions and compulsions cause significant distress in daily life, people generally struggle up to 10 years before seeking treatment. As for every illness, early intervention is key. Moreover, normal treatment is often experienced as difficult and aversive, leading to high drop out rates (Leahy, 2007). Until today there has been no real practical solution for self-help that is enjoyable enough to encourage people to continue with their treatment. This is where our game is supposed to be valuable.
CHAPTER II

LITERATURE REVIEW

Obsessive-Compulsive Disorder

OCD is a neurobiological disorder characterized by obsessive thoughts and compulsive actions, such as cleaning, checking, counting, or hoarding. Individuals who suffer from OCD become caught up in a pattern of repetitive thoughts and behaviors that cause significant distress. In clinical OCD, those repetitive behaviors occupy at least one hour per day – but usually more. Obsessions often lead to anxiety, while compulsions allow individuals temporary relief from that anxiety. Hand washing, for example, may reduce the anxiety produced by thoughts of contamination. Hence, compulsions become negatively reinforced by taking away something uncomfortable and anxiety inducing, causing individuals to be caught up in a negative reinforcement loop (see Fig. 1).

Although individuals realize that their obsessions are senseless, unwanted, unreasonable and excessive, they face great difficulty in overcoming them. The extreme feeling of dread patients experience, makes it seemingly impossible for the patients to stop listening to their thoughts and acting on them (Abramowitz, 2008; Abramowitz & Jacoby, 2014; Belayachi, 2010; Bolwig, Hansen, Merkin, & Pritchep, 2007; Doron & Moulding, 2009; Ecker & Gönner, 2009; Evans, Lewis, & Iobst, 2004, etc.)
With a lifetime prevalence of 2 - 3%, OCD counts as one of the most common psychiatric disorders (Karno, Golding, Sorensen, & Burnam, 1988; Evans, Lewis, & Iobst, 2004). Every fortieth person suffers from clinical OCD, while approximately 10 percent of the population shows subclinical symptoms (thoughts are intrusive, but do not impair the ability to function in daily life). Taken together, almost 12.5 percent of the population experience OCD symptoms at some point in their lives. OCD is more common in women than men and usually manifests at an age of 6-15 years for males and 20-29 years for females. Familial predisposition points to a genetic role in OCD. In childhood onset OCD, compulsions tend to emerge significantly earlier than obsession (Rasmussen and Eisen, 1990).

Even though OCD causes significant impairment of everyday functioning, it often takes up to 10 years until individuals look for professional help for the first time, and on average, another six years until they receive treatment, with another four years until they are given the appropriate treatment (Rasmussen and Eisen, 1990, Whitaker et al., 1990).

Common treatment methods are Cognitive Behavioral Therapy, Exposure and Response Prevention (ERP), as well as pharmacological treatment in the form of
serotonin reuptake inhibitors (SRI). In ERP, exposure is intended to intentionally evoke anxiety by confronting patients with a situation that induces fear in the patient (e.g., touching a toilet seat), while not exhibiting the feared consequences. Response prevention involves refraining from compulsive behavior (e.g., no washing for the rest of the day) (Abramowitz, 1997; Abramowitz, Taylor, & McKay, 2005; Himle & Franklin, 2009; Khodarahimi, 2009). Even though ERP treatment was found to be very effective, people often report great difficulties and discomfort with the treatment leading to low compliance and high dropout rates (25%) (Menzies & De Silva, 2003; Leahy, 2007; Whittal & McLean, 1999). Around 75% of patients that showed clinically significant improvement after successful treatment, still report unwanted intrusions and difficulties in coping (Fisher & Wells, 2005). Additionally, there seems to be little support for the subclinical population, who don’t feel the need for a therapeutic intervention yet or just don’t feel ready yet to confront themselves with their underlying anxiety (Leahy, 2007). This is where our mobile app is expected to be valuable. It should provide an opportunity for self-help for both clinical and subclinical populations with OCD.

Inhibition Control Training

As previously mentioned, one of the goals of the system is to train OCD patients in their ability to resist their urge to perform a specific behavior, such as cleaning. The training addresses their inner tendency to act on an impulse, which is triggered by anxiety inducing situations, such as touching a doorknob associated with bacteria and contamination. But what exactly is an impulse and how is it related to compulsion? And how can we strengthen an individual’s resistance to those impulses?
In the following chapter we will first describe the underlying mechanism of impulses and compulsions and how they evolve. Second, we will present a theoretical framework supporting our assumption that training inhibition control can decrease compulsions. At the end of this chapter, we will discuss several paradigms that measure inhibitory control and elaborate how those paradigms can be used for training.

Compulsions and Impulses

An impulse is a sudden strong and unreflective urge or desire to act (English & English, 1958). It arises when a global motivation (e.g. hunger) meets specific activating stimuli in the environment (e.g. a hamburger). Impulses are directed toward temporary gratification (Ainslie, 1975). Most unconstrained impulsive behavior interferes with long-term goals (e.g. being healthy) (Baumeister, & Boone 2004; Bogg & Roberts, 2004) and can be inappropriate in a given situation or for a person’s current state, goals or plans (i.e. eating during a conference meeting) (Dalley, Everitt, & Robbins, 2011; Koob and Volkow, 2010).

Compulsions refer to acting despite conscious intent of the contrary. People who suffer from compulsions repeat certain kinds of behavior over and over again despite its inappropriateness, and are unable to inhibit this behavior (Bari & Robbins, 2013; Robbins, Grillan, Smith, de Wit, Ersche, 2012).

Hereby, it is important to mention, that individuals are usually susceptible to very specific stimuli in the environment, which activate strong urges to perform certain behaviors (Bari & Robbins, 2013). In the case of compulsive washers, for example, it is environmental stimuli associated with contamination and germs that trigger those impulses. It has been suggested that those associations evolve by classical conditioning,
in which neutral objects become associated with fear and anxiety through some negative event. Obsessions and compulsions are maintained by operant conditioning, because fear and anxiety are reduced by engaging in repetitive behavior and become negatively reinforced (Two stage Theory of Fear, Mowrer, 1960; Stanley & Turner, 1996).

Clearly, without an obsession triggering a strong desire, urge or habit there would be no need for inhibition, whereas fully functional inhibition control would keep those urges under control and prevent impulsive or compulsive behavior (Bari & Robbins, 2013). In other words, both compulsivity and impulsivity result from failures of response inhibition or top-down cognitive control (Dalley, Everitt & Robbins, 2011) and have been found to be impaired in patients with OCD. OCD sufferers show decreased ability to inhibit responses, even for affectively neutral stimuli (Penadés et al., 2007 Bannon, Gonsalvez, Croft, and Boyce, 2002). Example studies in this regard will be described later.

We argue that by training patients in their inhibitory control performance, we can strengthen their ability to better resist incoming urges. While conventional therapies, such as Exposure and Response Prevention, aim at reducing or extinguishing compulsions by breaking the maladaptive associations between stimulus and fear (Donamayor, Dinani, Römisch, Ye, & Münte, 2014; Stanley & Turner, 1996), inhibitory control training focuses on building the skills patients need to gain back control over their behavior. We argue that prior inhibitory control training would not just equip patients with the necessary skills, but would also build patients’ confidence to confront their anxiety and inappropriate beliefs.
So far, inhibitory control trainings have been successfully used in order to decrease people’s urge for unhealthy food and alcohol (Houben, 2011; Houben & Jansen, 2011; Houben, Havermans & Nederkoorn, 2012; Berkman, Kahn & Merchant, 2014; Benikos, Johnstone & Roodenrys, 2013; Nederkoorn & Houben & Hofmann, 2010; Schapkin, Falkenstein & Marks, 2007). For example, Houben (2011) found that participants with low inhibitory control abilities consumed more chips, nuts and M&M in a taste test prior to the manipulation than participants with high inhibitory control abilities. After four blocks of 64 trials (approximately 2 min) inhibitory control training, food consumption of those with low inhibitory control decreased significantly. After the training, both groups (high and low inhibitory control) consumed the same amount of high calorie food. A similar experiment was conducted by Houben, Nederkoorn, Wiers and Jansen (2011) with heavy drinking students. They found that training people for just a short period of time could decrease the implicit attractiveness of alcohol and overall alcohol consumption.

We intend to extend inhibitory control trainings to an obsessive-compulsive disorder. In the following, we will look more closely at the different subtypes of inhibitory control, along with the assessment paradigms and training possibilities attached to each.

**Subtypes of Inhibitory Control:**

**Action restraint vs. action cancellation**

In general, ‘inhibitory control’ refers to the ability to cancel, interrupt or withhold intended or already initiated cognitive or motor processes (Aron, 2011; Chamberlain et al., 2005; Manuel et al., 2010). Inhibitory control is the umbrella term for
behavioral inhibition and cognitive inhibition, as depicted in Figure 2 (Bari & Robbins, 2013).

While cognitive inhibition refers to the control over internal cognitions, such as thoughts, memories, perceptions and emotions, behavioral inhibition refers to the control over externally manifested motoric actions, such as grabbing an object (Chamberlain et al., 2005; Bari & Robbins, 2013). According to Chamberlain et al. (2005), obsessions can be characterized in terms of failure to inhibit ongoing thoughts, mental rituals or inappropriate cognitive strategies and therefore represent deficits in cognitive inhibition. Compulsions, in turn, seem to reflect failures in behavioral inhibition and lack of control over motoric activities.

As depicted in Figure 2, behavioral inhibition is further divided into two types: action restraint and action cancellation. Action restraint refers to the inhibition of a planned response (i.e. eating chocolate) and is established in accordance to an
individual’s goal (i.e. being healthy). In this type of inhibition, representations of goal-relevant information need to be sustained in order to bias cognitive processes and behavioral responses (Aron, 2011; Bari & Robbins, 2013; Braver, 2012; Jahfari, Stinear, Claffey, Verbruggen, & Logan, 2009). Action cancellation, in contrast, refers to inhibition of an action that has already started (i.e. stop washing hands) (Eagle, Bari, & Robbins, 2008; Schachar et al., 2007).

OCD patients report not only difficulties in stopping an ongoing repetitive, compulsive action, but are also more susceptible for impulsive reactions, especially in the presence of an anxiety-inducing stimulus (i.e. doorknob associated with contamination). Hence, inhibitory control deficits in action restraint best represent patients’ increased impulsivity, whereas difficulties in cancelling or stopping ongoing actions best represents patients’ increased compulsivity.

Well-established paradigms to assess the mechanisms of action restraint and action cancellation are the Go/Nogo paradigm and the Stop-Signal paradigm, respectively. The Go/Nogo task assesses action restraint, the Stop-Signal task measures action cancellation. Both tasks have been successfully used in inhibitory control trainings and performance deficits have been found in OCD patients. Consequently, we decided to use those two tasks in our mobile application.

**Action Cancellation:**

**The Stop-Signal Paradigm**

In the stop-signal paradigm, subjects perform a primary choice reaction task (e.g. press left key when a blue object is presented, press right key when a yellow object is presented). On some occasions, the go stimulus is followed by a stop signal (e.g. an
auditory tone or visual cue) instructing subjects not to respond to that trial. Here, subjects need to withhold their ongoing response to the preceding go stimulus of the primary task. Response inhibition in the stop-signal paradigm is comparable to a horse race between two processes, a go process that generates a response to the primary choice reaction task, and a stop process that responds to the stop-signal. Response inhibition is successful when the stop-signal process finishes before the go process. Response inhibition is unsuccessful when the go process finishes before the stop process (Logan & Cowan, 1984; van Boxtel, van der Molen, Jennings, & Brunia, 2001; Verbruggen & Logan, 2009; Verbruggen et al., 2014). Good inhibition performance is indicated by a shorter Stop Signal Reaction Time (SSRT), which represents the time between the occurrence of a stop signal and successful suppression of a motor response to the preceding Go signal. It is important to note that the point in time can vary when the stop signals occurs. The shorter the delay between the stimulus and the stop signal (stop-signal delay, SSD), the higher the probability that the person can successfully inhibit the ongoing response (Spierer et al. 2013).

**Action Restraint: The Go/Nogo Paradigm**

In the Go/Nogo paradigm, participants are asked to respond as fast as possible to a set of stimuli termed as Go stimuli, while withholding their responses to another set of stimuli, called NoGo stimuli (e.g. press a response key for a blue cross, but do not press the response key for a yellow cross). Inhibition performance is indicated by reaction times to Go stimuli and the number of false responses to NoGo stimuli (false alarms).
Inhibitory Control Deficits in OCD patients

Specifically in tasks measuring action restraint (Go/Nogo) and action cancellation (SST), empirical evidence shows deficits for patients with OCD. For example, Pénades et al. (2007) compared OCD patients with healthy subjects regarding the previously described different inhibitory functions; motor response inhibition with a Go/NoGo task and inhibition of a triggered motor response with a Stop Signal task. The researchers found that OCD patients performed significantly worse than controls in both tasks. Significant differences between OCD and healthy patients in the SSRT (longer RT) and Stop-Signal Delay were observed in the Stop-Signal Task. In the Go/NoGo task, successful inhibition was 25% lower than inhibition of healthy people. No task performance differences were found regarding the different OCD subtypes of checking, washing, slowness, and doubting. These findings reveal that all OCD subtypes show significant impairment in their inhibitory control (Pénades et al., 2007).

Compared to patients with panic disorder, individuals with OCD made significantly more errors on NoGo stimuli (false alarms) and reacted faster to Go stimuli (Bannon, Gonsalvez, Croft, and Boyce, 2002), indicating deficits in behavioral inhibition. Bannon et al. (2002) assume that these deficits may explain the repetitive nature of patients’ compulsions.

From a neurobiological point of view, it has been suggested that OCD sufferers’ inability to ignore their own intrusive thoughts results from impairment in fronto-striatal circuits, specifically the orbito-frontal cortex, anterior cingulate cortex and basal ganglia regions (Jenike et al., 1996; Menzies, 2008; Pujol et al, 2004; Rosenberg et
The main cause of OCD seems to be a dysfunction of the basal ganglia. Both, anterior cingulate cortex (ACC) and orbito-frontal cortex (OFC) communicate with the basal ganglia (BG) and were found to be hyperactive in OCD (Gehring, Goss, Coles, Meyer, & Donchin, 1993; Gehring, Himle, & Nisenson, 2000). When excited, these structures’ error detection and inhibition ability is increased. When stimulated beyond normal ranges (hyperactivated), like in OCD, those brain structures cannot accurately detect errors and fire at inappropriate times. As a result, OFC and ACC send excessive erroneous messages to the basal ganglia communicating a problem, stimulating the OCD sufferer to correct the error with compulsive behavior. This is what patients report as a sense of dread, feeling that something is wrong, or inability to stop. In order to inhibit behavior that is difficult to terminate, conscious effort must continually be invested. OCD patients are caught up in a state of “brain lock”, in which the three brain areas are over stimulated or “locked” together (Doherty et al., 2001; Schwartz, 1997).

In essence, the patient’s automatic inhibitory control mechanism, the basal ganglia, is dysfunctional. Hence, it would be beneficial for those patients to improve the skills of inhibitory control. In order to solve these problem, other parts of the brain need to take over tasks in which the basal ganglia seems to fail. This can be done by involving and training the frontal cortex in inhibitory control (Houdé et al., 2000). In the following section, we will discuss how inhibitory control can be trained.

Trainability of Inhibitory Control

Previously described inhibition control tasks have not just been used for assessment, but also for training. By consistently mapping stimuli onto stopping
responses, people can strengthen their ability to inhibit responses to those stimuli. Recent research confirms that training not only increases inhibitory control over those stimuli (Verbruggen & Logan, 2008, 2009), but also changes the evaluation of those stimuli (Veiling et al., 2008; Houben et al., 2011).

**Development of automatic forms of inhibition**

The ability to automatically inhibit unwanted responses can be strengthened by consistently and repeatedly mapping Nogo stimuli onto stopping responses (Verbruggen and Logan, 2008, 2009; Spierer et al., 2013). At the beginning of the training, reactions to Go and non-reactions to NoGo stimuli, will demand conscious effort of top-down control processes. Verbruggen and Logan (2008) argue that over the course of training with stable stimuli-response associations, automatic, bottom-up processes will gradually replace top-down controlled processes. In other words, after a certain amount of training sessions, stimuli signaling a required stopping response will directly trigger inhibition without taking the slower route of top-down executive control. After repeated Go/NoGo training higher order, top-down forms of control will no longer be required and learned stimulus-response associations will become automated (Spierer, Chavan, & Manuel, 2013, Shiffrin & Schneider, 1977; Logan, 1988; Verbruggen & Logan, 2008).

A number of studies have addressed the trainability of inhibitory control and found direct improvements in inhibition related task performance (Benikos, Johnstone, & Roodenrys, 2013; Berkman, Kahn, and Merchant, 2014; Dowsett and Livesey, 2000; Johnstone, Pfeffer, Barry, Clark, & Smith, 2005; Johnstone et al., 2012; Manuel, Bernasconi & Spierer, 2012; Manuel, Grivel, Bernasconi, Murray, & Spierer, 2010; Schapkin, Falkenstein, Marks, & Griefahn, 2007; Thorell et al., 2009).
Thorell et al. (2009), for example, conducted a study in which children, ages four to six years old, received five weeks of working memory and response inhibition training (Go/Nogo, SST, and Flanker task) with daily sessions of 15 minutes for five days per week. After those five weeks, the children showed significant improvements in working memory and response inhibition compared to before the training. These findings suggest, that working memory and inhibitory control can be trained.

Johnstone et al. (2012) conducted a study in which both, healthy children and children diagnosed with ADHD practiced inhibitory control with a Go/Nogo task for 25 days for 15-20 minutes per day. Both groups showed higher inhibitory control performance after the training. The children with ADHD also improved in spatial working memory, ignoring distracting stimuli, and sustained attention. Children without ADHD showed improvements in interference control as well. Most interestingly, the training effects were maintained six weeks after the training.

Benikos, Johnstone and Roodenrys (2014) further looked into Go/Nogo training effects with varying task difficulties. 60 adults were randomly assigned to one of three difficulty conditions. Participants in the low difficulty condition had 1000ms time to react on stimuli, whereas participants in the medium condition had 500ms time, and participants in the high difficulty condition had only 300ms time. The training was split in eight 15-20 minute long blocks and inhibition performance was compared between blocks. Results showed that performance in the Go/Nogo training was significantly influenced by task difficulty. Participants in the low and medium difficulty condition showed significant reduction in Go reaction time, while participants in the high difficulty condition showed a decline in inhibitory performance. These findings support the notion
of trainability of inhibition control, but also point towards a potential key role of task
difficulty in training. Based on these results, we decided to adapt task difficulty
according to individual inhibitory control performance in our training, at 500ms, 750ms,
and 1000ms, respectively.

**Devaluation of positive stimuli**
*(Behavior Stimulus Interaction Theory)*

Verbruggen and Logan (2008) and Veling (2008) further argue that training
effects will be even stronger when stopping responses are paired with stimuli that are
associated with something positive or pleasurable. In behavioral science it is well known
that positive or pleasurable objects elicit approach tendencies. However, before
responding to a positive object, we usually evaluate situational demands. These demands
can be consistent and indicate that an approach is desirable, or inconsistent and indicate
that an approach is undesirable. Inconsistent conditions prompt behavioral inhibition.
Those situations in which approach tendencies triggered by a positive stimulus (e.g.
seeing a glass of beer) and environmental demands signaling that the response is
unwanted (e.g. the glass of beer is not yours) collide, evoking a response conflict. In
order to solve this conflict, an evaluative mechanism is required which tags negative
affect to the approach-eliciting stimulus. Hence, inhibiting the approach reaction in such
conflicting situations will require an adaptive tuning of stimulus valence and lead to a
devaluation of the positive stimulus (Band & van Boxtel, 1999; Verbruggen & Logan,
2008; Veiling & Aarts; Veling, Holland, & van Knippenberg, 2008). Devaluing
positive stimuli, as described above, is known as Behavior Stimulus Interaction (BSI)
theory. The theory was conceptualized and tested by Veling, Holland, and van Knippenberg (2008).

Houben, Nederkoorn, Wiers, and Jansen (2011) tested Veling’s theory and found that practicing to stop pre-potent responses towards alcohol-related stimuli reduced excessive alcohol use via a devaluation of alcohol-related stimuli. In this study, 52 heavy drinking students performed a Go/Nogo task in which alcohol related stimuli were either paired with Go (beer/go condition) or with Nogo stimuli (beer/nogo condition). Houben et al. (2011) then compared participants’ attitude towards alcohol, measured with an Implicit Association Test (IAT), as well as participants’ weekly alcohol intake before and after the training. After the manipulation, participants in the beer/no-go condition showed significantly increased negative implicit attitudes toward alcohol stimuli and significant reduction in weekly alcohol consumption. Participants in the beer/go condition showed an increase in weekly alcohol increase, and a non-significant trend towards increased implicit positive attitude toward alcohol stimuli. Other studies, in which Houben and colleagues trained participants to inhibit food cues embedded in Go/Nogo and Stop Signal tasks led to similar results (Houben, 2011; Houben & Jansen, 2011; Houben et al., 2011).

Another example study comes from Houben and Jansen (2010), in which chocolate lovers were asked to either consistently inhibit responding (nogo condition), consistently respond (go condition) or respond only to during half the trials (control condition) to chocolate stimuli. Chocolate consumption was measured following the manipulation with a taste test. Participants in the chocolate/no-go condition showed significant decrease in their chocolate consumption. Houben and Jansen (2010) concluded that repeatedly practicing inhibitory control over food-related responses, even
for a short period of time can help people regain control over the consumption of high calorie food.

Consequently, for the purpose of our inhibitory control training, it seems beneficial to choose objects as Nogo stimuli that are associated with unwanted behavior. For OCD patients, such positive stimuli are those that take away anxiety stimuli that are usually associated with the individual’s compulsion. In the case of contamination/washing subtype, it is cleaning utensils that are associated with a behavior that takes away anxiety (negative reinforcement) and is therefore evaluated as something positive. In ordering compulsion, it is the order or logical arrangement of objects that patients associate with a positive feeling of relief after experiencing anxiety triggered by an experience of chaos or lack of control in any kind of aspect in their life. For the checking subtype, it is a closed door of a stove that is turned off that provides a positive feeling of security and assurance that nothing bad will happen. Presumably, pairing those OCD subtype specific stimuli with a stopping response, and developing a training that consistently demands to inhibit a response to these stimuli, will lead to a devaluation of the stimuli. We assume that such training will make it easier for patients to resist their cleaning, ordering, or checking urges.

**Re-evaluation of negative stimuli**

*(Counter-Conditioning)*

Lastly, it would be beneficial for our training to modify patient’s evaluation of bacteria or germs as something negative, aversive or frightening. We plan to accomplish this goal by using negatively evaluated germs as Go stimuli and a patient’s interaction with those germs with something positive, e.g. an in-game reward. This idea is based on
the principle of counter-conditioning. Counter-conditioning is defined as “conditioning a response to a stimulus that is incompatible with another response elicited by the same stimulus” (Martin & Pear, 2003, p. 411). Usually, germs elicit avoidance behavior in OCD patients. By rewarding patients for approaching the germs within the game, we can counter-condition patients’ response to the stimulus.

**Generalization and Transfer of Training Effects**

A question that often arises in the context of inhibitory control training is whether training effects can actually be transferred to daily life. Not much research has been done in this regard, however some studies have found promising effects. Houben (2011), for example, found generalization effects regarding high calorie food (SST), chocolate items (Go/NoGo), as well as alcohol consumption (Go/NoGo). Subjects consumed less chocolate, alcohol and high calorie food after the training compared to before. Effect on drinking behavior lasted up to one week (Spierer et al., 2013). Thorell et al. (2009) found that Go/NoGo training could improve inhibitory control, but did not transfer to the SST or other executive tasks. This supports the notion that the two response inhibition tasks measure different kinds of inhibition. Spierer et al. (2013) argued that “when domain-general inhibitory control network is modified by training, the effects of the training will influence subsequent complex behavior involving the same inhibitory control component” (p. 6).

**Conclusion**

In this chapter, we described several theories and studies supporting our assumption that training OCD patients’ inhibitory control skills could improve the
patients’ resilience to incoming cleaning urges and their ability to stop ongoing cleaning behavior. In the following section, we will discuss methods of decreasing maladaptive fear responses to dirty environments.

Exposure Treatment

As mentioned in the introduction, we aim to break the maladaptive behavior chain of OCD at three different links (see Figure 1). The chapter above described how we could approach the OCD patients’ impulsivity and compulsivity. This chapter will now target patient’s germ phobia and focus on decreasing patients’ susceptibility to certain stimuli (i.e. dirt and germs). A conventional and effective treatment procedure for phobias is systematic desensitization as a form of exposure therapy, which we have mapped onto a game environment.

In the following chapter, we will first describe the procedure of systematic desensitization, then address the benefit of biofeedback as part of the treatment and conclude with a description of hardware that can be used as the biofeedback component.

Systematic desensitization

Systematic desensitization is a form of exposure therapy and counter-conditioning, and is commonly used to reduce avoidance behavior. It refers to continuous pairing of aversive stimuli with anxiety competing relaxation. In this method, the patient is relaxed and then will gradually be exposed to anxiety-provoking stimuli. The procedure starts with the weakest item on the list of aversive stimuli, the patient is presented with gradually incremental degrees of aversive stimuli in the presence of a
relaxed affective state. The treatment can be considered successful when the patient is completely desensitized to the most upsetting stimulus in the anxiety hierarchy (Davison, 1968).

A major problem with the systematic desensitization technique is, that it is not very enjoyable, but, in fact, rather aversive and therefore difficult to implement in a mobile app where there is no therapist guiding the patient through the systematic desensitization process. We hope to overcome this problem by using game mechanics that motivate and encourage patients to practice by rewarding them for their success. The benefit of games on learning will be discussed in the Chapter 3.

However, before entering the literature of game mechanics, we want to explore biofeedback as another valuable component in the system. Why this is valuable and how we plan to use this will be presented next.

**Biofeedback as proxy for relaxation**

Since patients with OCD have a difficult time trusting their own feelings, our system needed to account for their high level of uncertainty. OCD patients have been shown to be less accurate in evaluating internal states, to be less confident in judging these states, and show an increased compensatory reliance on proxies for these states (Jacoby, Fabricant, Leonard, Riemann, & Abramowitz, 2013; Lazarov, Dar, Oded, & Liberman, 2010; Lazarov, Liberman, Hermesh, and Dar, 2014; Vikas & Chandrasekaran, 2011). OCD patients often use proxies, such as rules, procedures, behaviors or environmental stimuli as substitutes for internal states. OCD patients report those proxies as more easily discernible or less ambiguous (Lazarov et al., 2010, 2014). A study by Lazarov et al. (2010) showed that patients with more severe OCD were less accurate in
estimating their level of relaxation than patients who had less severe OCD. However, when patients were given biofeedback, both groups performed equally well in estimating their level of relaxation (Lazarov et al, 2010, 2014). These results suggest that including Biofeedback into the system can be very valuable, especially considering the fact that patients don’t receive feedback through a therapist or other person while playing a game.

There are several possible biofeedback parameters that could be measured. The most common ones are monitoring a player’s heart rate, heart rate variability or galvanic skin response. With new EEG technology, it is now possible to also monitor ones’ emotional state – in our case, level of arousal. Those EEG biofeedback systems are called Brain-Computer-Interfaces (BCI) (Ferreira, de Miranda, de Miranda, & Sakamoto, 2013; Fink, 2004) which are described below. Since OCD is a disorder of the brain, we decided to include EEG biofeedback in our system.

**Brain-Computer Interfaces**

We are planning to support the user’s learning experience with a wearable EEG-headset. EEG devices have mainly been used as a) communication tool for disabled people (Rebsamen et al., 2006, 2007), b) game controller for video games (Lécuyer et al, 2007; Pires, Torres, Casaleiro, Nunes, & Castelo-Branco, 2011; van Vliet et al., 2012), or c) a game controller for Neurofeedback training (Birbaumer, Murguialday, Weber, & Montoya, 2009; Hammond, 2006, 2011; Huster, Mokom, Enriquez-Geppert, & Herrmann, 2014). In recent years, the development of new technology has made it possible to expand the EEG applications out of the lab with the help of newly developed wireless EEG devices or BCIs. Since those wireless headsets now meet consumer demands for comfort, price, mobility, and ease-of-use, they have became increasingly
popular in the field of serious game design (Larsen & Wang, 2011; Mihajlovic, Grundlehner, Vullers, & Penders, 2014; Wang, Sourina, & Nguyen, 2010). In our system, we used the BCI device from Neurosky to measure a user’s mental relaxation level, which in turn controls the game environment.

**Neurosky Mindwave Mobile**

The American company, Neurosky, has developed a low cost, single channel, dry sensor system for consumer applications of EEG technology called the Mindwave Mobile. It contains one electrode at the forehead above the eye (Fp1) and one reference electrode, which is to be clipped at the ear (see Figure 4).

![Neurosky Mindwave Mobile](http://press.neurosky.com/MindWaveMobile.html)

*Figure 4. Image (left) and functional Diagram (right) of Neurosky Mindwave Mobile headset. Used with permission from Neurosky Mindwave Mobile. (2015). Retrieved from: http://press.neurosky.com/MindWaveMobile.html*

The headset transfers data via Bluetooth and communicates wirelessly with other devices such as mobile phones or computers. It allows the measurement of brainwaves while interacting with the computer or mobile device. The headset is, with a
price of $79, the cheapest BCI on the market. It allows the user to record EEG data without the need for expertise with EEG. Moreover it provides two algorithms for states of focus and meditation. For the purpose of this project the meditation algorithm came in handy. We used the meditation algorithm to measure the change from an anxious and fearful mind state to a relaxed one.

**Conclusion**

In this chapter, we described how exposing patients to dirty environments within a mobile game can transform maladaptive associations between germs or dirt and fear. The next part of the chapter will target the question of how serious games can foster intrinsic motivation and self-efficacy in patients.

**Serious Games**

In the first parts of this chapter, we described how inhibitory control training and exposure treatment could improve patients’ conditions. In the following part we want to address the question of how to motivate people to actually use the training system.

In health care, patients are often required to undergo procedures that are painful (i.e. chemotherapy), aversive (i.e. exposure therapy) or just boring and mundane (e.g. taking pills, regular exercise). Often, people don’t take advantage of available health care or don’t comply with a treatment plan, even if those plans are be necessary to maintain or improve health (Kato, 2010). As indicated in the beginning of this chapter, this is also the case for patients with OCD. Drop out rates are at 25%, and patients take up to 10 years before they seek treatment. Exposure and Response Prevention confronts patients with their anxiety and is therefore a rather aversive experience (Kyrios, 2003;
Leahy, 2007; Menzies & De Silve, 2003; Rasmussen & Eisen, 1990; Whitaker et al., 1990; Whittal & McLean, 1990). Similarly, skills trainings, such as inhibitory control training, can actually become very tedious and boring.

An innovative and new way to tackle these psychological and behavioral obstacles is video games (Kato, 2010). While most video games aim to create a fun experience, there is a category of games that go beyond entertainment: serious games. The term ‘serious games’ refers to games whose main purpose is to train and educate (Annetta, 2010; Rieber, 1996). Serious games use the attractive shape of games to serve a serious purpose (Mader, Natkin, and Levioeux, 2012) and attempt to entertain while achieving change of some kind. They may target a change in attitude, beliefs, knowledge, or skills, whereas the ultimate goal is typically to change behavior (Baranowski & Buday, 2008; Thompson, 2012).

The behavioral change we intend to create with our system is a decrease in obsessive and compulsive behavior by improving inhibitory control skills and decreasing emotional responses to germs and dirt. As indicated above, major challenges we face in this context is the insipidity of inhibitory control tasks on the one side, and aversion of exposure therapy on the other side. This is where game environments can be beneficial. Serious games are powerful tools that allow engaging users in an activity that would otherwise be boring, effortful, and aversive (Kato, 2010; Malone, 1981, 1982).

Two example games that were successful in increasing engagement and motivation of otherwise mundane and repetitive tasks are GameWheel and Packy and Marlon. GameWheels uses common racing games like Need for Speed for faster physical rehabilitation. In this game, players have to maneuver their wheelchair in order to control
the game, which allows them to reach fitness goals faster (O’Connor et al., 2000). *Packy and Marlon* is a game targeted at the children with diabetes and aims at increasing children’s compliance in measuring their insulin level. In this game, children play two elephants in a diabetes camp. The players’ task is to keep rats that steal healthy food and diabetes supplies from the camp by successfully managing their insulin level and food intake. Compared to the control group, patients who played the game for six months showed greater self-efficacy and improved diabetes management, increased communication with parents about diabetes, and most interestingly a decrease by 77% in diabetes-related emergency and urgent care visits (Brown et al, 1997, Kato, 2010).

Games have also been found to function as powerful method that allows patients to manage aversive or shameful aspects of their illness (Kato, 2010). A game that was able reach such a goal is *Re-Mission*. *Re-Mission* targets adolescents and young adults with cancer, who typically show decreased treatment compliance. In this game, patients have to navigate a nanobot through the body of young cancer patients, shoot cancer cells with chemotherapy and radiation, and manage side effects of the cancer treatment. Playing the game over the course of three month improved their compliance in taking their medicine, increased their knowledge about cancer, improved patients’ self-efficacy in managing their illness and even led to higher levels of chemotherapy effects compared to patients who played Indiana Jones as control game (Kato, Cole, Bradlyn, & Pollock, 2008; Kato, 2010).

These examples show, how play and entertainment can function as foundation for serious interventions in health care. Through their use of fiction and narration, serious games make intervention more interesting and entertaining, hence fostering the
compliance necessary for successful treatment (Kato et al., 2008; Lu, Baranowski, Thompson, & Buday, 2012; Green & Brock, 2000).

How Games change Behavior

Instead of trying to change behavior directly, behavioral scientists usually attempt to change mediators of a target behavior, which in turn would lead to change in behavior (Baranowski, Lin, Wetter, Resnicow, & Hearn, 1997). One such example is the Elaboration-Likelihood Model by Petty & Cacioppa (1986), which tries to modify one’s attention and involvement with a product to change one’s attitude and behavior. Other important mediators come from the social-cognitive theory by Bandura (1986), which identified knowledge, skills, personal mastery, and self-efficacy as essential for behavior change. Self-determination theory by Ryan and Deci (2000) revealed autonomy and competence as important mediators. Lastly, transportation theory by Green and Brock (2000) identified immersion and attention as powerful mediators of behavior change.

Interestingly, serious games have the possibility to target most, if not all, these mediators through game play; hence fostering behavior change in an efficient and entertaining way. How this can be done exactly, will be discussed in the following section.

Enjoyment and Flow through Challenge & Fun

As exemplified above, gamifying a treatment can increase engagement and compliance (McCallum, 2012). Hereby it is important to understand that fun is not an ingredient we can induce into treatment, but something we want to get out of it (Michael & Chen, 2005). According to Koster (2013), fun is the emotional side effect of learning, or as Csikszentmihalyi (1990, 2014) described in his Theory of Flow, fun or enjoyment is
a sense of achievement that occurs when one’s skills match the task’s challenges.
Challenges exceeding competence may lead to frustration or anxiety, whereas
competence that exceeds challenge may lead to boredom (Csikzentmihalyi, 1990). The
optimal middle path is what Csikszentmihalyi refers to as flow, an experience that is “so
gratifying that people are willing to do it for its own sake, with little concern for what
they will get out of it” (p. 71).

Applying this theory to the challenges we face with our system, this would
suggest that by making the inhibitory control game more difficult and exposure treatment
a little bit less, we can create a system that motivates players to practice and persist in the
training

Games are useful tools that allow flexible adjustment of task difficulty to the
player’s level of competence (Baranowski & Buday, 2008; Byrne, 2004; Quick,
Atkinson, & Lin, 2012; Thompson et al., 2010; Thompson, 2012). A common feature
video games commonly use to adjust difficulty is levels (Baranowski et al., 2013). Levels
allow for variations in goals and rewards. Whether a game is motivating or demotivating
depends on its comparison to standards or goals. If players receive the feedback that their
performance matches the goals perfectly, the game is too easy and motivation declines.
Similarly, when feedback indicates that performance is constantly below desired
standards, a game is too difficult and motivation declines as well. Motivation and goal
commitment are highest when the goal is clear and confidence in eventual success is
high. High goal commitment and confidence in success is highest, when feedback is
given in a way that rewards a user for performance, but also provides enough space for
improvement (Garris, Ahlers, & Driskell, 2002). The experience of joy we get while
playing a game with optimal challenge functions as a positive feedback mechanism that gets us to repeat an activity over and over again (Micheal & Chen, 2005).

**Immersion through Narration**

Another concept closely related to flow is immersion. Immersion refers to the degree to which individuals concentrate on and become absorbed in an activity (Garris et al., 2002). It is a process in which cognitive and affective resources are concentrated (Green & Brock, 2000). Immersion has been found to attract and maintain attention and to foster behavioral change (Baranowski et al., 2009; Thompson et al., 2006; Thompson, 2012).

A common strategy game designers use to create immersive experiences, is narration and story telling (Tjan et al., 2014). Narrative is defined as “any cohesive and coherent story with an identifiable beginning, middle, and end that provides information about scene, characters, and conflict, raises unanswered questions or unresolved conflict, and provides resolution” (Hinyard & Kreuter, 2007, p. 778). Green and Brock (2000) defined the idea of becoming immersed into a narrative world as transportation. Even though both, the concepts of immersion and transportation, are very similar, transportation is typically used in the context of non-interactive media, such as films or novels, while immersion is used within interactive media like video games (Lu et al., 2002).

A good example for a health game using narration to foster change in health behavior is *Escape from Diab*. This game was developed for childhood obesity
prevention and tells the story of Deejay, an athletic boy who accidentally falls into Diab, a world, which Deejay and his friends can only escape by adopting a healthier lifestyle (Baranowski et al., 2009; Lu et al., 2002).

For our game ShmutzCastle, we chose to use the metaphor of war between Obsession and Compulsion and invasion in a town named Cerebrum (Latin for brain) to emphasize that OCD does not have to be a part of a patient’s life and change is possible. The player’s task is to bring peace to the town by making friends with germs. The peace component should reflect a patient’s ultimate desire to stop the war in their head. The fact that peace can only be accomplished by making friends with germs portrays an important message in itself – that is, the belief that germs are not always things to fear and avoid at all costs.

Change of Beliefs through Persuasive Narrations

Green, Garst and Brock (2004) describe several ways in which narratives can influence people’s attitudes and beliefs. One prominent way of changing people’s beliefs is narrative immersion. Research in the context of Green and Brock’s transportation theory found that being immersed into a story could decrease players’ resistance to story messages (Lu et al., 2012). This effect might be due to the fact that players don’t want to destroy the pleasure of a narrative immersion and are therefore more willing to suspend disbelief (Lu et al., 20012). A study by Green and Brock (2000) showed that highly immersed readers found significantly fewer false passages in a story and showed greater acceptance for story content than less immersed readers. A study by Moyer-Gusé and
Nabi (2010) found that stories increased an audience’s likelihood to invest in desired health behaviors.

In the case of *ShmutzCastle*, we are trying to transfer the message that bacteria are not as bad as compulsive cleaners might think. This is an essential aspect of OCD treatment. Changing such strong beliefs, however, is very difficult and convincing someone by solely presenting facts might not account well enough for the affective component attached to those beliefs. Wrapping this message into a game story, however, might be more effective.

According to the Elaboration-Likelihood Model, the persuasiveness of a message is influenced by the perceived trustworthiness, attractiveness, and likability of the message source. In the case of games, a game character or avatar can function as the message source. Hence, in serious games the protagonist should embody these characteristics, while the antagonist should show opposite characteristics (Thompson, 2012).

**Experience of Mastery and Self-Efficacy through Narration**

Moreover, it has been found that narrative experiences can become personal experiences (Green et al., 2004). A well-written game narration allows the player to enter a fictional world and take the role of the character or avatar in the game. Activities in the virtual world may then be linked to the real world (Thompson, 2012). By allowing the player to perform a task without real world consequences of failure, games can boost a player’s confidence in mastering similar real-world problems (Garris et al., 2002).
Moreover, observing the game character master a difficult task has been found to reflect positively on confidence and self-efficacy. Self-efficacy refers to believing in one’s capabilities to achieve different levels of performance and is a key construct of Social Cognitive Theory (Bandura, 1977, 1982). A person’s efficacy expectations mediates how well knowledge and skill can be applied to achieve behavioral change. Hereby, it is important to understand that self-efficacy is not a personality trait, but refers to particular behaviors and specific situations (Bandura, 1977, 1982, 1986; Strecher et al., 1986; Lu et al., 2012).

One way to modify efficacy expectation is through vicarious experiences. Observing others, so called ‘models’, in successfully performing a behavior and receiving internal or external reward for it, is an efficient way to learn and can reflect positively on ones personal experience of self-efficacy and feelings of competence (Thompson, 2012). In the case of games, avatars or game characters can function as models.

A good example for a game that successfully used modeling to change behavior is *Bronkie the Bronchiasaurus*. It is an asthma self-care game in which players: a) manage the character’s asthma, b) avoid asthma triggers as a way of experimental learning, and c) make choices for the character and observe the consequences (Kato, 2013). Studies on the game found that players’ knowledge, self-concept, self-care behavior and self-efficacy improved compared to the control group (Lieberman, 2001).

In *ShmutzCastle*, observing the protagonist defeat its antagonists, Obsess and Repeticia, which personalize contamination obsessions and cleaning compulsions, might increase one’s self-efficacy and confidence and in managing one’s OCD.
Another way in which narrative and game play may reflect positively on self-efficacy is by providing positive arousal. Bandura (1977, 1982) suggested that people make inferences about their capacities from physiological cues, such as emotional arousal. Hence, joyful experience during mastering game challenges might be a good way to learn.

Moreover, not just by observing the avatar’s mastery within the story, but also by observing oneself master the game tasks themselves, has been found to reflect positively on confidence and self-efficacy (Thompson, 2012, Kato, 2010). OCD patients that experience themselves in successfully decreasing their anxiety level and increasing relaxation while walking through dirty game environments, might afterwards feel more confident that they can do the same in the real world. Similarly, receiving positive in-game feedback about increase in inhibitory control skills should boost patients’ confidence in being able to resist cleaning urges in real life. And this is what brings us to the next point, feedback.

**Self-Efficacy through Feedback and Reward**

Well-crafted feedback can enhance self-efficacy (Schunk, 1986) and feeling of competence (Ryan & Deci, 2000). For example, Schunk and Swartz (1993) assessed the influence of goal setting and progress feedback on self-efficacy and writing achievement for fourth graders. In this experiment, children were taught writing strategies and then asked to write a paragraph. Half of the children received feedback on their progress in learning to use the strategy. The children who received feedback, reported higher self-
efficacy and higher value of the progress they made in strategy learning. They also scored higher on posttest skills and wrote more words per paragraph.

Games, when designed well, have potential for great feedback systems. Immediate performance feedback can be given via sounds or graphics, such as green checkmarks, red crosses, words appearing on the screen, numeric values or symbols like stars or coins. Encouraging words like ‘great’ or ‘good gob’ can enhance players’ sense of accomplishment and personal pride in the job.

Another form of feedback is reward. Rewards can come in various forms. A very common method of rewarding is receiving points, coins, badges or a rank on a leadership board. Rewards for completing a level can be given in the form of short victory animations of the character or just by allowing access to the next level (Byrne, 2004).

To summarize, game mechanics, such as level design, narration, and feedback are powerful tools that influence intrinsic motivation and self-efficacy by creating enjoyment and immersion, and providing valuable feedback. Before we describe how we integrated those elements into our game, we will first discuss more about Games for Health as a subcategory of serious games.

Types of serious games

Within the field of serious games, there are two main types that can be distinguished: Games for Education and Games for Health. Since, our system is a game for health, we will elaborate more on this in the following part of this chapter and review some state-of-the-art research on video games and their impact on health.
Games for Health

Sawyer and Smith (2008) proposed a specific taxonomy to categorize different games in the health sector (Djaouti, Alvarez, Jessel, Methel, & Molinier, 2007; Mader, Natkin, and Levioeux, 2012). This taxonomy has two parameters: function and public. Function categorizes games in preventive, therapeutic, and educational, assessment and informatics. The parameter public refers to whether the games are targeted at personal, professional practice, research and academia, and public health. Our game falls in the category of a therapeutic game designed for personal use, as well as involvement in professional practice with the goal to help patients in managing their disease. In the following section, we will further elaborate on therapeutic games in particular.

Therapeutic games. According to the Concise Dictionary of Modern Medicine, therapy is defined as “a general term for any form of management of a particular condition; treatment intended and expected to alleviate a disease or disorder; any technique of recovery, which may be medical, psychiatric, or psychological” (Segen, 2006). According to this definition, games can be considered therapeutic as well.

Within the field of therapeutic games, Mader et al. (2012) distinguished direct and indirect therapeutic games. Direct therapeutic games aim at improving specific characteristics of a disease through the game play itself. One such game is Brick ‘a’ break developed by Burke et al. (2009, 2010). It trains stroke patients in their motor control ability in the upper limbs. Virtual Iraq (Rizzo et al., 2010) is a game that targets the mental health of soldiers and trains them to suppress post-traumatic stress.

Alternatively, indirect therapeutic games aim at supporting the main therapy by improving a patient’s behavior, mood, or observance. While some indirect therapeutic
games provide knowledge about a disease and its treatment, others try to make patients more committed to their treatment protocol. Another set of indirect therapeutic games target caregivers, patients’ relatives or scientific research. For example, *SnowWorld* is a virtual reality game aimed at distracting highly burned patients during the bandage replacement in order to facilitate the caregiver’s work (Hoffman et al., 2008). *Elude* is an example that helps patient’s relatives to understand how it feels to be depressive (Rusch, 2012). Our game falls in the category of a direct therapeutic game.

**Therapeutic Neurogames.** A very new field of games that has just recently evolved is therapeutic neurogames (Moritz et al., 2011). These are games that use biofeedback sensors to enhance game play. One such game is *Mindlight*, which targets children with anxiety disorders. Similar to our game, *Mindlight* uses exposure techniques and supports the experience with an EEG headset that measure the child’s relaxation level. In this game, children need to navigate little Arthur through a scary house full of shadows. Whenever the child become anxious, a light on Arthur’s head dims down and harmless furniture will appear like monsters. When the player relaxes, he/she can see the true gestalt of the rooms. This game was an inspiring source for our game (Armstrong, 2014).

A similar game that uses heart rate sensors as biofeedback is *Nevermind*, a horror game targeted to people with post-traumatic stress disorder. In *Nevermind*, the player enters the surreal subconscous of trauma victims. The player needs to solve puzzles to uncover memories of the patient while wandering through a bizarre and sometimes terrifying world. Whenever the player becomes too tense, the game will become harder. It might blur out or become milky. In the future, this game will also be
available as virtual reality game (Reynolds, 2013). A study Lobel et al. (2015), testing the effect of Nevermind on real life emotion regulation, found that the less time players needed to calm themselves down after negative arousal, the more likely they were to resolve emotional conflict through reappraisal.

**Conclusion**

In the last part of this chapter, we discussed how game mechanics such as level design, narration, and feedback affect intrinsic motivation, change in beliefs and self-efficacy through means of enjoyment, immersion, and feedback. Concretely, we found that enjoyment, flow and immersion are powerful tools that transform otherwise boring or aversive tasks into intrinsically motivating challenges. We further described, how narration can facilitate behavioral change through means of persuasion and increased self-efficacy. We concluded with describing how games can provide feedback and reward.

We completed this chapter by presenting different types of serious games with special focus on games for health. In this context, we presented some examples of therapeutic games. In this context, we emphasisd two therapeutic games that used biofeedback mechanisms and provided inspiration for ShmutzCastle.

**Summary**

In this literature review, we first described how inhibitory control training and virtual exposure to dirty environments can improve the symptoms of OCD patients. Second, we argued that games with its different motivational characteristics might
increase the likelihood that patients’ practice inhibitory control and exposure repeatedly. In the following chapter, we will describe *ShmutzCastle* in detail.

As a short recap, the aim of our game is to approach three sides of the OCD problem. The first is to improve patients’ ability to resist their cleaning impulses. A second part of the training is designed to help patients to stop compulsive and repetitive behavior. Lastly, the training includes an exposure component aimed at desensitizing patients to contamination stimuli, thereby decreasing patient’s susceptibility to certain stimuli. Hence, the system addresses a patient’s impulsivity, compulsivity and obsession (see Figure 3) and tries to break the behavioral chain on several aspects. Those tasks have been built into the game.

*Figure 4: Stimulus-Response Chain and Intervention Point*
CHAPTER III

METHODOLOGY

Terminology

Before we describe the system, it is necessary to clarify some terminology. In the following, we will use the word ‘player’ in order to refer to the person interacting with the game environment. We refrain from using the word ‘patient’ in order to represent the whole spectrum of possible users of the game (i.e. OCD patients, clinicians, etc.). Character, in contrast, refers to the animated figure or avatar within the game environment.

Procedure

Over the course of the year we drafted, built, rejected and rebuilt several versions of the game. The end result is three prototypes exemplifying each the three system components, the GoNogo task, the Stop-Signal task and the exposure task. The game art was either drawn by myself or downloaded from the Unity Asset Store, a website where animators provide their 3D animations for free. Hence, each art peace was copyright free. Germs and cleaning utensils were created by Forrest Spade, a student of the APCG department at California State University, Chico, who allowed me to use his graphics.
Target Group

The game is targeted at people who suffer from OCD in some form and report subclinical or clinical OCD symptoms in terms of cleaning compulsion and contamination obsessions. It was designed with a target age of 18+ years in mind, but can also be used by younger age groups. The game has no upper age limits, but people are required to be able to use a smartphone and to set up a Bluetooth connection with the EEG headset.

Game Description

Game Overview

*ShmutzCastle* is a third-person therapeutic neurogame that plays in a medium sized, modern town called Cerebrum (Latin for brain). The player, represented by an avatar named *Evan*, will run through different environments, such as streets, shopping malls, train stations, bus stations, houses, restaurants, grocery stores, etc. Within each environment, *Evan* will have to accomplish three missions. Each of the three missions incorporates one of the three psychological interventions described in the literature review (Go/Nogo, Stop-Signal, and exposure task). A game narrative frames the three missions and its corresponding psychological tasks into a meaningful story line that is metaphorically relevant to the OCD patient and that provides instructions about how to play the game.

In the following, we will first present the general narrative. Second, we will describe each mission separately with its specific narrative, its corresponding psychological task and elaborate on how it is played as well as how game mechanics, such as feedback and difficulty, have been implemented. And third, we will discuss how
a possible level structure could look like and graph out a game flow. Please refer to the interactive prototypes provided along with this paper. Links to those can be found in Appendix A.

Narrative

The following narrative will be presented to the player in an animated form:

“Once upon a time, there was a town called Cerebrum (see Fig 5). Cerebrum used to be a very happy place, populated by the sprightly and cheery Shmutzie folk. This, however, was about to change as Repeticia and Obsess came to invade the town. Obsess is so afraid of losing his power that he suppresses, frightens and threatens Shmutzies to such an extent that they started hiding in dark places. Whenever Shmutzies do not comply, Repeticia sends out Cleaners of her Army of Hygiene. Only a few Shmutzies were able to stay resistant, but are too disorganized to start a revolution. Now you have been called to town and commissioned to bring back peace.”

Then players will be presented with the first mission and its corresponding narrative, which we will describe in the next section. Each mission specific narrative will be presented in an animated form during the first levels of the game play.

The player will be represented by a game character called Evan (see Fig. 6.). Evan is a rather shy and not so confident, but faithful little boy with a big heart. Evan is not very sure whether he can master this big challenge of defeating Obsess and Repeticia, but his sense of justice motivates him to jump over his shadow every now and then. Every time Evan accomplishes a set of tasks, his confidence will rise and he will get a stronger looking appearance.
Repeticia is a personification of cleaning compulsion and directs the Army of Hygiene, figures that look like cleaning utensils (see Fig. 7). Obsess is the personification of obsessions and spreads fear over the town. Repeticia and Obsess do not play an active role during the game, but have more of a symbolic function. They will appear in form of short animations to carry the narrative. Shmutzies are figures that look like germs (see Fig. 8). Their name is an adaptation of the German word “Schmutz”, which means “dirt”. In order to defeat Repetetica and Obsess, Evan has to make friends with the Shmutzies.
Mission 1: Collect

Narrative

“Obsess and Repetica have heard that you are in town and know about your plan to start a revolution. In order to destroy your plan, they took all rebellious Shmutzies and put them in trucks to throw them in the castle’s oriel. The trucks are already on their way to the castle. But you are lucky! The Shmutzies were able to open the backdoors of the trucks in order to escape. One by one, a Shmutzie will jump out of the trucks. Cleaners will jump too and try to catch them again. Run behind the trucks and pick the Shmutzies up before the Cleaners do. Your goal is to get at least 75% of the Shmutzies otherwise you will loose all of them to the Cleaners. Don’t collect more than seven Cleaners or you run the risk that you lose all your Smutzies as well.”

Psychological Intervention: Go/Nogo Task

This mission is a gamified version of the Go/Nogo task aimed at training OCD patients in better resisting incoming cleaning impulses. Specifically, we used 3D models of germs (Shmutzies) as Go stimuli and 3D models of cleaning utensils, such as soaps, hand sanitizers, disinfection wipes, etc. (Cleaners) as Nogo stimuli. The player’s task is to collect as many germs as possible, while refraining from collecting cleaning utensils.

Game Play

In this game, a character is running on a three-lane street behind two trucks loaded with germs and cleaning utensils (see Fig. 9). The character’s default running path is the middle lane. One truck is driving on the right lane, while the other one is driving on
the left lane. Both trucks are loaded with an equal amount of objects (cleaning utensils and germs), of which 30% are Nogos (cleaning utensils). The fact that the trucks’ backdoors are open causes objects to fall out. This will happen every 1.5 – 2 seconds. The player then has 500 - 1000ms to respond to the object that fell on the street. The player can collect the objects by swiping to the right or left. By doing so, the character (Evan) will move to the corresponding lane, run into the game object and collect it. If the object is a germ (Shmutzie), the player should change the lane and collect the object. If it is a cleaning utensil (Cleaner), the player should stay in the middle lane and leave the object on the ground. After having collected an object, the character will automatically move back to the middle lane.

Each time the player correctly collects a germ, a sparkling effect around the character will appear and a progress bar at the bottom of the screen will move one step closer to the end goal. Each time the player falsely collects a cleaning utensil, the character will light up red and players will loose one of their health points. Health is indicated by a heart at the top right corner of the screen, on top of which the player can read the number of remaining health points. After losing all their health points, players will die and have to start over. Similarly, if a player misses too many germs, he/she will not be able to collect enough germs before the trucks are empty. If this is the case, players will have to start over again as well. The player can win the level by collecting a certain number of germs (i.e. 21 germs in the first level). Whenever the player masters a level’s goal, a new level will be unlocked.
Figure 9. Screenshots of Go/Nogo Task. Top left: Go object; top middle: Sparkling effect to reward for correct collection of Go object; top right: Nogo object; bottom left: feedback for falsely collecting Nogo object; bottom middle: Winner Screen; bottom right: menu settings.

**Feedback.** Performance feedback will be given in three ways: 1) visual effects, 2) encouraging words based on Go reaction time, and 3) numeric values about reaction time, missed Go’s, and falsely collected Nogos.

In regard to visual feedback, we used a sparkling effect around the character to indicate a correct response. To indicate a false response, the character will turn red for
a short amount of time. In future versions we plan to add sound effects, as well as little success and failure animations after having won or lost a task.

To encourage that the player reacts fast, the words ‘perfect’, ‘great’, and ‘good’ will appear on the screen depending on how quick the player changes the lane. This will only be shown when the object on the ground was a Go stimulus (Go reaction time). A ‘perfect’ can be reached when the RT is under 250ms, a ‘great’ will appear when the RT is under 300ms and a ‘good’ will appear when players react faster than 350ms. Everything slower than 350ms won’t result in reinforcing words. These numbers are an estimate based on reaction time results in Benikos et al. (2013) study using the Go/Nogo task. They found reaction times to vary around 250-300ms in the optimal difficulty condition. Hence, it is ‘great’ if players are in the range of 250-300ms. If players get close to this range, they will be reinforced with the word ‘good’, whereas everything faster than that will be scored with ‘perfect’.

Additionally, reaction times (RT) to Go stimuli (germs) will be displayed on the screen (see Fig. 8) in the form of two numeric values 1) the individual RTs of each current reaction, and 2) the mean RT calculated based on all RTs measured within a game. Number of falsely collected Nogos (cleaning utensils) will be indicated by the number in the heart, whereas number of correctly collected Gos (germs) will be indicated by the progress bar at the bottom of the screen.

**Difficulty.** The level of difficulty will be adjusted in three ways: change in time to react or reaction time deadlines (RTD; 1000ms, 750ms, or 500ms), change in target number of collected germs, and change in number of health points the player can lose before his character dies.
In regard to RTD, studies have either not modified RTD (e.g. Jodo and Inoue, 1990), or have used auto-adaptive RTD manipulations (Manuel et al., 2010). A study by Benikos et al. (2013) investigated an optimal level of difficulty and found 500ms as optimal RTD for learning, while 300ms was too difficult and 1000ms was too easy (refer to study description in the literature review for more detail). For the prototype, we built three reaction time deadlines, representing a low, medium and high difficulty. In the easy conditions, players have 1000ms time to react, in the medium one they have 750ms, in the hard one they have only 500ms. These three steps demonstrate possible variations of task difficulty and can be adjusted manually in the prototype’s menu settings. However, in the final version of the game, difficulty will be preset and incorporated into the levels. In order to create a path of difficulty adjustment, it is necessary to consult with an experienced level designer, as well as to test the prototype on OCD patients that might – due to their decreased inhibitory control abilities - experience 1000ms time to react as more difficult than healthy players. For the prototype we did not include the 300ms option tested by Benikos et al. (2013), since it did not provide interpretable results and was already too difficult for healthy patients. To answer the question whether we can go below 500ms RTD after a certain amount of practice can only be answered through user testing.

In the first level, the player needs to collect 75% of the germs and should not collect more than seven cleaning utensils in order to win the game. The higher the level, the higher will be the target percentage and the lower will be the available health points. Here, the numbers seven and 75% are arbitrarily set. Since, experimental tasks usually do
not incorporate an option of winning and losing, research could not provide guidelines for this.

All three variables, RTD, target percentage and number of health points, contribute to the variable difficulty that should be incorporated in an algorithm of task difficulty. The optimal path of task difficulty would require consultation with a level designer and user testing.

**Mission 2: Convince**

**Narrative**

“In order to fight Obsess and Repeticia you will need more Shmutzies to help you. The rebellious Shmutzies you are trying to rescue from the oriel will not be enough to win this fight. Find more Shmutzies in the town and convince them that the fear Obsession spreads is not appropriate. Convince them to join your peace corps. But be careful. Those Shmutzies have built a strong defense mechanism against Cleaners. They have learned to change their appearance and disguise themselves as dirt layer on top of furniture. Since Shmutzies don’t know about your good intentions yet, they will try to spread fear in you. Keep a calm mind and you are golden.”

**Psychological Intervention: Exposure**

Mission 2 aims at reducing patient’s germ phobia. The goal is to extinguish a patient’s fear response to dirty surfaces or objects associated with contamination. In order to accomplish this goal, we used techniques of graduated exposure therapy or systematic desensitization and integrated it into the game play. In the technique of systematic desensitization people are confronted with anxiety-inducing situations, while remaining a relaxed affective state. As mentioned in the literature review, we use the Neurosky
Mindwave Mobile headset to measures the player’s level of relaxation. The player will mainly influence the game by modifying his/her relaxation.

**Game Play**

In the game, the player navigates *Evan* through dirty environments, such as the dirty bathroom depicted in Figure 10. If the player is afraid of germs, this will evoke feelings of anxiety or tension. The player’s task is to transform the ugly looking germs into nice comic style germs by keeping a relaxed and calm mind state. The player’s relaxation level is indicated by the blue bar at the bottom of the screen, which ranges from 0 (not relaxed at all) to 100 (very relaxed). The player needs to adjust his/her relaxation above a certain threshold in order to transform germs from ugly and realistic to nice and comic style. The underlying message is that when you become anxious, you cannot see the world how it is and everything looks bad. However, if you keep calm you can see the true nature of things. Only when extreme emotions are kept silent, logic can speak.

Regions that contain germs that can be transformed are indicated by a glow around them. Once the player has transformed all the germs available, the glow will disappear. The germs the player transforms in one room will then follow him and will be available for Mission 3. The goal of the task is to transform as many germs as possible within a certain time frame.
Figure 10. Screenshot of Exposure Task.

Feedback. The blue bar at the bottom of the screen, as well as the depictive transformation of the germs, provides player with direct feedback about their relaxation performance.

Difficulty. Over the course of the game, rooms will become dirtier and dirtier. As described in the literature review, the procedure of systematic desensitization starts with the weakest item on the list of aversive situations and gradually raises degrees of averseness in the presence of a relaxed affective state. For the future, we are planning to develop an algorithm for auto-adaptive difficulty adjustment that increases dirtiness of environments based on relaxation performance of previous in-game exposures.

Another way of modifying difficulty is by adjusting the threshold of relaxation players need to reach in order to transform germs. In our prototype we arbitrarily set it to 50%. Testing the prototype on people with germ phobia would provide insight into where to set the threshold. User testing would also help in finding a good balance between two the difficulty variables, threshold and dirtiness of the environment.
A possible option could be to first gradually increase the relaxation threshold until 90% and then increase the level of dirtiness by one step.

**Mission 3: Defeat**

**Narrative**

“Now after you have collected and convinced a number of *Shmutzies* it is time for a first attack. Go to the castle and help *Shmutzies* to storm it. One way of doing so is by catapulting *Shmutzies* through the windows. Be careful! *Cleaners* inside the castle will try to defend their territory.”

**Psychological Intervention: Stop-Signal Task**

Mission 3 aims at training patients to better stop repetitive and ongoing cleaning behavior. This is done by mapping the Stop Signal Task onto a game environment.

**Game Play**

The player will be presented with a house facade of a castle with four windows (see Fig. 11). At the bottom of the castle are all the germs (*Shmutzies*) the player has collected in the previous two missions. The player’s task is to storm the castle by catapulting the germs through the castle’s windows. Most of the time these windows will be closed. Every 1.5 seconds (inter-stimulus interval), however, one of the windows will open (Go signal) for one second. By tapping on the window, the player can then catapult a germ through the window.

This task would be fairly easy, if there were not cleaning utensils (*Cleaners*) sitting in the castle trying to defend their territory. On some occasions after a window has been opened, cleaning utensils will appear in the window and shoot soap bubbles out of
the window (Stop-Signal). Whenever a cleaning utensil appears, the player should refrain from tapping on the open window. In this task, these cleaning utensils resemble the stop signal, prompting the player to stop his/her already initiated response to the open window. If the player fails to stop his response, the germ will be caught in the soap bubble and fly away. The player will have lost one germ. The player’s task is to avoid the soap bubbles, while trying to catapult 60% of the germs available in the castle (numbers are calculated based on level 1 calculations). Similar to the Go/Nogo task the number 60% is arbitrarily set due to lack of winning and losing components in research tasks.

Stop Signals will appear in 30% of all cases. The delay between a window opening and a cleaning utensil appearing can vary between 100 and 500ms. It starts out with a Stop Signal Delay (SSD) of 50ms. Every time the player is successful in stopping his/her response, the SSD 50ms will be added to the previous SSD. Whenever stopping is unsuccessful, 50ms will be subtracted from the previous SSD. This way the game will automatically adapt to the player’s inhibition performance. Those numbers stem from Logan and Cowan (1984), the inventors of the stop signal paradigm.

The player wins the level after having catapulted 60% of all available germs through the windows. The player looses the game and has to start over, when more than 40% of the germs get caught in the soap bubbles.
Figure 11. Screenshots of Stop-Signal Task. Left: Inter-stimulus interval, middle: Stop signal trial, right: Go trial.

Feedback. To provide patients with feedback about their inhibitory control performance, we will measure Stop-Signal Reaction Times (SSRT) of each trial.

Difficulty. Aside from automatic adjustment of stop-signal delay, difficulty will be adjusted in form of percentage of germs players have to catapult through the windows. Again, the optimal path of difficulty adjustment will be determined by user testing and in consultation with an experienced level designer.

Levels and Game Flow

The town has several environments, such as shopping malls, grocery store, train stations, restaurants, market streets, etc., basically any environment within a town setting where there could be germs. Within each environment, the player has to accomplish the three missions described above. In other words, the player has to collect, convince and defeat. The number of germs available during defeating the castle (SST)
will depend on the number of germs collected and convinced in the Go/Nogo and Exposure task.

Each mission resembles a level. Missions describe the overall task itself and repeat each other during the game. A level is a specific mission with a specific difficulty setting, numeric goal (i.e. number of germs to collect), and visual appearance (i.e. street, mall, train, etc). Whenever a level goal is accomplished, a new level will be unlocked and becomes accessible to the player. Within one environment, there are three levels. The player needs to accomplish each of the three levels in order to unlock an environment (see Fig. 12). In other words, the player needs to collect, convince and defeat within a particular environment (i.e. train station) to bring peace to this particular environment.

Each time the player unlocks an environment *Evan* will receive more power indicated by a stronger appearance (i.e. more muscles, growing in height, etc.). Over the course of the game, the player will bring peace to all environments of the town. *Obsess*

After more than two hours of play, it will become night, prompting the player to stop playing and come back the next day. This allows us to regulate playing time and avoid that they play through the game within only a week. If the player doesn’t come back, parts of his win will go back to the cleaners. However, the user has a pool of seven days within one month he/she can use to announce a ‘war break’. This would allow the user to have play-free days.
With *ShmutzCastle* we created a game that incorporates game mechanics of both inhibitory control tasks and exposure task. We provided three interactive, playable prototypes to demonstrate how each of those tasks could be mapped onto the game. Through means of feedback and narrative, we created a game that is intrinsically motivating and fosters persistent re-engagement.

*Figure 12.* Game Flow

Summary
CHAPTER III

SUMMARY, CONCLUSION AND FUTURE DIRECTIONS

Summary

In the literature review, we first described how inhibitory control training can train patients in better resisting cleaning impulses. Second, we elaborated on how virtual exposure to dirty environments can decrease patients’ maladaptive fear response to dirty environments and how EEG biofeedback could improve learning. Third, we discussed how a serious game could increase the likelihood that patients’ practice inhibitory control tasks and exposure repeatedly. We concluded by summarizing existing games in the field of Games for Health. In the methods section, we then described our game in detail and how we implemented findings from the literature review.

Conclusion

With ShmutzCastle we built the first therapeutic neurogame targeted to OCD patients. The game incorporates several evidence-based interventions including inhibitory control training, counter-conditioning, systematic desensitization and neurofeedback that together produce an immersive game through which OCD patients learn to defeat obsessions and compulsion.
The inhibitory control training aims at increasing OCD patients’ resistance to impulses and compulsive actions and to empower patients through positive feedback. The exposure component allows OCD patients to overcome their germ phobia by practicing to master anxiety-inducing situations without real-world consequences.

In the design of the system we paid special attention to the averseness and discomfort patients describe with exposure treatment and accounted for the insipidity of repetitive skills trainings. We incorporated inhibitory control training and exposure into a game environment to make the first one more challenging and the latter a little bit less. We found game principles of narrative, optimal difficulty adjustment and feedback to be powerful tools to foster intrinsic motivation, persistent re-engagement, persuasion and self-efficacy. By augmenting the experience with cutting edge BCI technology, we not only provide feedback about emotional states, but also accounted for patient’s high level of uncertainty and decreased access to internal states.

We developed a narrative that transforms the patient’s desire of stopping the war inside his head into a meaningful metaphor. Game play allows the patient to directly interact and be part of the narrative. In the game patients experience success in defeating Obsess and Repeticia, the personifications of obsession and compulsion, and can identify with the character that struggles, but also gains confidence over the course of the game.

Lastly, we target patients’ maladaptive belief of germs as something harmful or bad. With the help of an immersive narrative and a likable character, we aim to persuade patients’ that germs are nothing to fear, but necessary for survival.

In essence, ShmutzCastle makes treatment and self-help more enjoyable, while being grounded in scientific findings. Instead of trying to replace a therapist with an app,
we build a system that complements treatment and existing self-help options. By
designing the game in form of a mobile app, psychological intervention becomes
accessible and portable.

Current Status of Development and Future Directions

Currently, the game consists of three separate prototypes exemplifying
gamified versions of the Go/Nogo, the Stop-Signal and the exposure task. Level structure
and game flow have only been conceptualized, but not visualized yet. What seems like
three separate games right now, needs to be integrated into one higher order level
structure and embedded into the game narrative. Moreover, animations that carry
storyline and instructions for game play are still missing.

In the future, we plan to consult with an experienced level designer to develop
an optimal path of difficulty adjustment. In order to create a valuable experience for
patients, as well as a useful tool for clinicians, we will conduct interviews with both and
ask for feedback on the prototypes. Initial contacts to OCD patients and clinicians have
been made and interviews will be pursued in the next months. We will try to get feedback
from OCD patients of different age groups and with varying symptom severity. The
feedback will then be incorporated into the next version of the game.

Meanwhile, we will either build a team of game designers in Germany, or
look for outsourcing opportunities. A game design document will be finished in the next
weeks and given to gaming companies for quotation. Contacts have been initiated
already. From July on we will look for investors and funding. In fall we plan to look out
for Master’s or PhD students that are interested in helping to conduct an efficacy studies.
We specifically want to investigate whether ShmutzCastle increases inhibitory control skills and decreases germ phobia, as well as whether effects transfer to OCD symptom severity and self-efficacy. Major challenges will be to find an appropriate game for the active control group. Moreover, we plan to collect EEG data in the inhibitory control tasks to determine whether the training has an effect on the brain. Concretely, we will look into event-related potentials.

The fact that we won a Neurogaming Hackathon in May 2015 with ShmutzCastle, which allowed us to exhibit at the Neurogaming Conference for three days, provided us with valuable feedback and contacts. The positive feedback we got from game designers, psychologists and clinicians, as well as clinicians expressing their interest in using such a game in their treatment, is a major motivation point of pursuing with this project in the future.

In the future we might separate the games into two parts, an inhibitory control training targeted to the subclinical population, and an exposure game targeted at complementing clinical practice. This would allow integrating more advanced technology into the exposure component without constraints of high cost and decreased willingness of patients to pay for the devices. Specifically, we were thinking of enhancing the exposure treatment by integrating virtual reality headsets in future work. The inhibitory control training, on the other hand, should not require any additional devices. This allows easy access to the game in the hope to increase patients’ self-efficacy and motivation to approach their germ phobia in further treatment. Whether those games will be separated or not is still in discussion.
A last idea we want to share is building a service structure around those games. Concretely, we were thinking of making the inhibitory control performance transparent and comparing data between patients. This would allow patients to see how they rank in inhibitory control skills compared to other OCD patients with similar symptom severity. Moreover, patients who use the exposure game might receive more game points when transferring the exposure within the game to the real world. By making a video of themselves facing anxiety-inducing situations (i.e. walking into a subway station and touching the handles) and posting it in a closed forum, patients could receive extra point or unlock special features in the game. Other patients could rate their videos for courage or other aspects, which in turn might create a motivating environment for everyone. We started conceptualizing a website in which patients make an account and profile that stores their personal data of the game and gives them access to the forum. Moreover, patients should be allowed to send their data to clinicians. The concept of this service structure is still in the idea phase. We hope get valuable ideas through interviews with clinicians and patients.
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LINKS OF PROTOTYPES

Go/Nogo Task: http://forrestspade.com/controlit

Stop-Signal Task: http://forrestspade.com/controlit/sst

Exposure Task (Demo video): https://www.youtube.com/watch?v=wzjtyRF5NF0
Hi Linda, thanks for reaching out to us. You can absolutely use the 2 images in your thesis.

Also, if you feel so inclined, or you would like to share more about this project with us, we would love to hear more about what you did with the MindWave Mobile.

Cheers,
Andrea Shukis
NeuroSky
Director of Global Marketing

On Tuesday, June 9, 2015, Linda <weberlindamarie@gmail.com> wrote:

Dear Andrea,

I used the Neurosky Mindwave Mobile in my Master’s project and would like to include two pictures of the headset (see below) in my thesis paper.

As I understood, those images are copyrighted. Hence, I would like to ask for permission to use those images?

Regards,

Linda Weber

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Cheers!
Andrea

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