MASTER

Reducing anxiety with pulsating light as a breathing guide

Horst, M.

Award date:
2012

Reducing Anxiety with Pulsating Light as a Breathing Guide

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Summary

For the quality of MRI images it is important that the part of the human body being scanned is in the same place in each image (Murphy & Brunberg, 1997). However, people undergoing an MRI-scan often are anxious, up to 25% of the patients experience moderate to severe anxiety (McIsaac, Thordarson, Shafran, Rachman, & Poole, 1998), and anxious people tend to move more (Murphy & Brunberg, 1997). This decreases the quality of the images, which can lead to the necessity to redo the scan. For this, and for a better patient experience, it is important to help patients to become less anxious. One way to promote relaxation is paced (slow and deep) breathing (Peng et al., 2004). Besides a relaxation response, an important advantage of using paced breathing during an MRI scan is that the breathing pattern of the patient becomes more predictable, which may further improve the quality of the images.

A technology that can be used inside a scanner to influence breathing rate might be pulsating light. That is, research suggested that pulsating light might help people to breathe in a slow pace (Brandt, 2010). For the implementation of such a device for anxious people in an MRI scanner, it is important to investigate whether people can also follow the pulsating light in an anxious state. Although previous research showed that breathing exercises could help to relax in anxious situations, the symptoms of anxiety could interfere with the task to follow the light with one's breathing.

The main research question is formulated as follows: Does breathing in sync with slowly pulsating light reduce anxiety? Furthermore, we investigated the effect of anxiety on the ability to follow the light. It was expected that breathing with the pulsating light would reduce anxiety, and that following the pulsating light would be harder for anxious people. Furthermore, we used a haptic interface to measure continuous subjective anxiety. It was expected that participants would squeeze more in the haptic interface if they experienced more anxiety. To answer these questions an experiment (n = 42) with a 1 (pulsating light) by 2 (anxiety induction condition vs. neutral condition) between subjects design was conducted in which participants were exposed to either anxiety inducing or neutral film clips. A pilot test was done to see the trends of anxiety changes during a relaxation period without pulsating light, results suggested that the effect of the anxiety induction maintained after this relaxation period. In the experiment, participants would breath along with pulsating light in the relaxation period. The pulsating light presented participants a breathing pace going from their own breathing frequency to 6 breaths per minute in a period of 8 minutes.

In line with our expectations, results of the experiment suggested that, anxiety was reduced when breathing along with pulsating light. Furthermore, after breathing with the pulsating light no differences were found in anxiety levels between conditions.

No evidence was found that breathing with the pulsating light was harder for anxious people. That is, no larger deviation from the presented pacer frequency was found for anxious people. Results of the experiment suggested that participants were able to follow the pulsating light on average for more than 80% of the time.

In line with our expectations, participants squeezed more often in the haptic interface as their anxiety levels increased according to the STAI-S. This suggests that squeezing as measured with the haptic interface can indeed be used as a continuous measure of anxiety, but further research is needed.

These results suggest that pulsating light could be implemented as a breathing guide for patients who have to undergo an MRI scan. However, we argue that it is important to also study the effects of pulsating light with higher anxiety levels of participants.

Keywords: Synchronous, paced breathing, pulsating light, anxiety, MRI

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1 Introduction

Patient experience is becoming a more important aspect in patient care, as studies suggest that it can be of influence on the medical and healing process (Vogel et al., 2012; Zapka et al., 1995). Studies have suggested that patient dissatisfaction is associated with disenrollment, and less compliance with the treatment (Zapka et al., 1995). During MRI procedures, patients often experience anxiety. During scanning, it has been reported that as many as 25% of patients experience moderate to severe anxiety (McIsaac et al., 1998). Anxiety in general is regarded as a common problem by radiographers (Tischler, Calton, Williams, & Cheetham, 2008). Especially for anxious people it is important to be able to calm down. Reducing anxiety during MRI procedures is important for three reasons. First, it will help patients to have a better experience with the procedure, which will in turn help them to be less anxious on potential follow-up scans. Second, the time needed to make a scan can potentially be decreased. Furthermore, when people are calm they tend to move less (Murphy & Brunberg, 1997), which may decrease the amount of rescans needed because of bad image quality due to movement.

For the quality of the MRI image, it is important that in the sequence of images the body and the organs are approximately in the same place (Murphy & Brunberg, 1997). Since the internal organs move along with the breathing pattern, especially for images of the torso it suddenly becomes very valuable to be able to predict the breathing pattern of the patient. For anxious people it can be hard to lay still and to control their breath on the command of the radiographer, because the feelings of anxiety usually go hand in hand with faster breathing and more movement of the body (Murphy & Brunberg, 1997). When doing our daily tasks, our breathing is regulated automatically, and we do not have to deal with this consciously (Douglas & Haldane, 1905). Depending on ones personal breathing pattern, subconscious breathing can be regular or irregular (Benchetrit, 2000). Especially when the natural subconscious breathing pattern is irregular, it is hard for the radiographer to predict when someone will reach the maximum exhalation. Techniques such as breath-holding can be used, but earlier research suggested that this technique can also cause more errors in the images due to compensation behavior in the breathing of the patient directly after they can no longer hold their breath (Thomason & Glover, 2008). Furthermore, they found that the depth of inhalation while breath-holding can vary over breath-holds, such that good calibration is sometimes prohibited.

For both the patient experience and for the quality of the images, reducing patient anxiety is crucial. Suggested is that paced breathing can elicit a relaxation response (Peng et al., 2004). Paced breathing could thus alleviate anxiety and reduce the associated movement. Paced breathing is characterized by its regular slow pace of 6 breaths per minute, and the use of abdominal deep breathing. This specific breathing frequency is ideal for the relaxation response because of resonance of several bodily processes that reinforce each other, increasing the impact of the relaxation response (Vaschillo, Vaschillo, & Lehrer, 2006). Besides calming the patient, in the situation of an MRI scan, a regular breathing pace could further improve the quality of the images, since the radiographer can make better predictions of the breathing pattern and the associated movements. Paced breathing during MRI procedures could thus lead to various advantages; shortening of the time needed for the MRI procedure, limiting the chance that an MRI-scan needs to be redone due to bad image quality and improvement of the patient experience by reducing anxiety.

Earlier research suggested that people were able to synchronize their breathing with different kinds of rhythms, such as rhythmic movement of the body (Rassler & Raabe, 2003) or sound (Gavish, 2010). Pulsating light might also be a cue with which people can synchronize their breathing. The current study investigated the effects of paced breathing, using pulsating light as a guide, on anxiety reduction, as well as the effects of anxiety on the ability to follow pulsating light. First, we will discuss the theoretical background. Topics such as anxiety and how anxiety is currently reduced in the medical context will be discussed, as well as topics such as breathing, and existing solutions for device guided breathing. A theoretical model will be presented that explains the hypothetical workings of breathing with pulsating light on psychological and physical aspects of the human body. The next section explains the experiments that were conducted and their results.

2 Theoretical Background

In the theoretical background, we will first discuss anxiety and how it can be measured. After this, we will discuss the strategies that can be applied to reduce anxiety, as well as the specific strategies for MRI procedures. Breathing is a central element for this study, as it is used in many strategies to reduce anxiety, and because our intervention includes breathing, and therefore investigated in more detail. Also the mechanisms behind this breathing technique, often referred to as paced breathing, will be discussed. Devices that make use of paced breathing are covered as well as the research into pulsating light used to accomplish relaxation.

2.1 Anxiety

Most people have experienced anxiety at one point in life (Zeidner & Matthews, 2011). It is a healthy reaction of the body to a perceived threat. The body releases the stress hormone adrenaline, and prepares for fight or flight (Zeidner & Matthews, 2011). When feeling anxious, one experiences subjective tension, nervousness, and worry. These subjective feelings often come accompanied with physiological arousal (Spielberger, Gorsuch, & Lushene, 1970). When experiencing anxiety, our body tries to cope with this and looks for solutions (Zeidner & Matthews, 2011). One will try to adapt the outcomes, by either changing the external situation (e.g. run away) or the internal situation (e.g. try to control the anxiety). Then the new situation will be reinterpret and the cycle continues (Zeidner & Matthews, 2011), a schematic overview of this can be seen in Figure 1.

We can distinguish two different forms of anxiety, state anxiety and trait anxiety. Trait anxiety refers to the general tendency of a person to be anxious, whereas state anxiety refers to anxiety experienced at one moment in time. Trait anxiety affects how one appraises a stressful situation, leading to a certain level of state anxiety (Zeidner & Matthews, 2011).

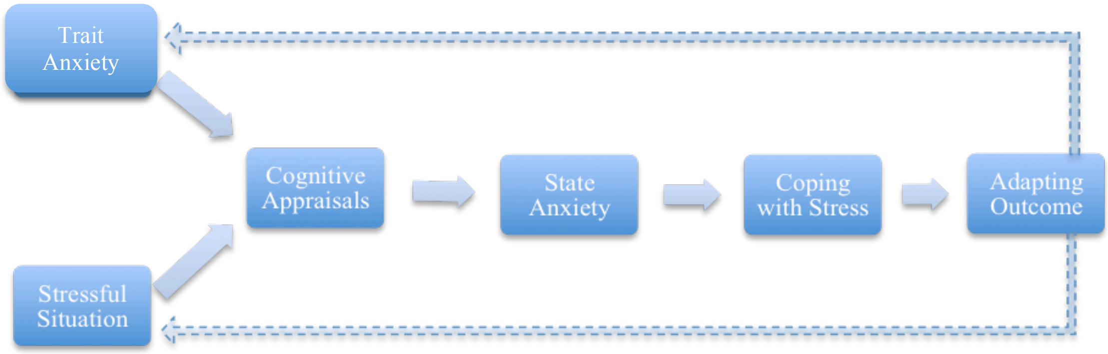


Figure 1. Interactions between state and trait aspects of anxiety. From Zeidner & Matthews (2011) Anxiety 101, p. 8

Anxiety can be experienced in different ranges from mild nervousness to panic. These different ranges of anxiety also come with different symptoms (Badger, 1994), and not all people will experience the same symptoms (Badger, 1994; Zeidner & Matthews, 2011). When experiencing mild anxiety, one can experience a heightened sensitivity to environmental stimuli and overall alertness, whereas moderate anxiety tends to result in decreased attentiveness, tremulousness and restlessness (Badger, 1994). The symptoms become more troublesome when anxiety increases. Also muscle tension may become more severe when anxiety increases (Sainsbury & Gibson, 1954). When experiencing severe anxiety, the symptoms can include disruption of thought processes and a decrease in the ability to make decisions and concentrate (Badger, 1994). When someone experiences panic, the anxiety is severe and acute, symptoms of panic include rapid heart rate, palpitations, shortness of breath and dizziness (Badger, 1994). Shortness of breath is characterized by breathing superficially with filled lungs, at a very high breathing rate.

Anxiety is a multifaceted phenomenon (Katz, Wilson, & Frazer, 1994; Zeidner & Matthews, 2011) that in the specific case of patients undergoing an MRI procedure, often involves fear of enclosed places (claustrophobia), pain, the unknown and worries about what the test might reveal (Katz et al., 1994).

In conclusion, there are many levels of severity in anxiety, and the symptoms can vary a lot per person. But the processes of trying to change the unpleasant state of anxiety, by trying to cope with the situation, are a part of the mechanism that holds for most. This means that although everybody has a different way of experiencing anxiety, the same coping techniques could be useful.

2.2 Measuring anxiety

Anxiety can be measured in multiple ways. One could have the emphasis on the psychological aspects, or more on the physical changes that occur with anxiety. This section will describe the most common used measures, as well as a new type of a continuous measure. Furthermore, complications of making physiological measurements inside an MRI scanner are briefly touched upon.

2.2.1 Questionnaires

Anxiety is commonly measured using standardized questionnaires such as the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970). It consists of two separate elements, one probing trait anxiety, which refers to the natural tendency of a person to feel anxious, and one probing state anxiety of a person, which refers to the anxiety experienced at that particular moment in time. The STAI has frequently been used in clinical context and is translated (and validated) in multiple languages (Iwata & Higuchi, 2000; Mook, van der Ploeg, & Kleijn, 2007).

Another questionnaire is the Differential Emotion Scale (DES). This can be used to assess discrete emotional states, among which anxiety. Because it is not focused just on anxiety, the context in which it is used is quite different from the context of the STAI. The DES questionnaire can for instance be used to assess the emotional effect of film clips. This was one of the questionnaires used by Schaefer and colleagues (2010), when working on a database of film clips categorized by the emotion it elicits. This is relevant for this study, as film clips will be used to induce anxiety.

2.2.2 Physiology

Physiological measures can very well be used as indicators of anxiety. Anxiety is generally indicated by an increase in skin conductance, increased heart rate and lower heart rate variability, a higher breathing rate, increased muscle tension and a higher core temperature (Kenner, 2009). It is important to note that these measures do not measure anxiety per se. For instance, increases in skin conductance can also be found when someone is feeling aroused.

Measuring physiological activity is generally done through sensors that are directly attached to the body. Since this can be bothering in some cases, more unobtrusive ways to measure physiological activity are being developed. An example is measuring heart rate with cameras. However, especially cardiac and respiratory measurements remain challenging, especially when people can move around (Postolache, Girão, Pinheiro, & Postolache, 2010). A consideration has to be made to decide what is more important, and most convenient depending on the context. For instance, in an MRI scan the problem of the user walking around is not an issue.

2.2.3 Continuously measuring anxiety

For the development of interventions to decrease anxiety it is important to be able to measure anxiety during the scan, to be able to tell whether their intervention works. Currently measurements of anxiety are often done via questionnaires such as the State-Trait Anxiety Inventory (STAI) or through physiological measurements. When asking about the experienced anxiety during the procedure afterwards, people tend to report about the worst moment of the procedure and the last moments of the procedure (Redelmeier & Kahneman, 1996). Although physiology can be used as a continuous measure, as mentioned before, people experience anxiety differently, such that the subjective anxiety can differ from the objective anxiety as measured by physiological activity. Therefore, a continuous subjective measure for anxiety would be desirable, especially to measure the patient's experience of anxiety.

There are techniques to have continuous measures, one example is prompting the person to indicate their state, but this was found to be highly intrusive and decreasing the external validity. To overcome this, the affective rating dial and a positive-negative effect meter were developed (Ruef & Levenson, 2007). People could rotate or slide respectively to indicate how they were feeling at the moment. Results suggested that as people became familiar with the device they could easily interact with the device, without it disturbing their interaction with for instance their spouse (Ruef & Levenson, 2007).

Recently a study was done to validate using a haptic interface as a continuous measure for anxiety (Horst, 2012), with a device that is suitable for use inside an MRI scan. Results suggested that this haptic interface could be used as a continuous measure of subjective anxiety.

2.2.4 Measuring Physiological activity and anxiety inside an MRI scanner

Inside an MRI scanner there is a very strong magnetic field, generally a 1.5 to 2 Tesla magnet will generate a magnetic field about 21.000 greater than earth's natural field ("Magnetic Resonance Safety Policy of UCSF," 2012). One can imagine that this has a huge impact on ferromagnetic objects in this field. The safety of the patient in this environment can thus be endangered by ferromagnetic objects, which can shoot through the air due to the magnetic field. But it also has an influence on measuring equipment, traditionally used for physiological measurements. For instance, the radio-frequency field may induce currents in wires, which potentially causes skin burns to the patient. Therefore, special devices have been developed to measure physiological parameters inside an MRI scanner. They make use of special isolated cables, radiotranslucent materials, such that no metal is used in the applied part, or MRI-compatible materials, such that no ferromagnetic metals are used ("Magnetic Resonance Safety Policy of UCSF," 2012).

An example of such a device is the wBTU, which uses characteristics such as air movement to measure breathing patterns. A small plastic air filled pillow is placed on the belly of the patient and secured with an elastic band. The breathing of the patient will cause pressure on the pillow, causing an airflow that goes through a plastic tube to the wBTU device, which can pick up the changes in airflow (Horst, 2012).

2.3 Reducing Anxiety in General

In the ideal situation, one possesses enough coping strategies to have the ability to adapt and maintain balanced, this equilibrium is also known as allostasis (Smith & Tausk, 2010). There is a broad range of different therapies that are offered to reduce anxiety. In general three approaches can be distinguished: Cognitive modification, alleviating stress response, and environmental interventions (Zeidner & Matthews, 2011). The environmental interventions have an external approach, and include adaptations in the direct environment. Preventing overload and making the environment more pleasant to be in, can already relieve some of the anxiety (Zeidner & Matthews, 2011). Cognitive modification focuses on appraising the situation more constructively and on developing coping skills. Also making the person more aware of his or her coping skills is an important aspect of cognitive modification. Both problem-focused coping as emotion-focused coping are part of this approach (Zeidner & Matthews, 2011). Alleviating stress response aims at reducing the stress response. One way to alleviate stress is controlling the breathing, which increases in pace as one is more anxious. An advantage of this approach is that the person will be provided with a technique to control the symptoms of anxiety and to relieve them. In case of anxiety, they can then reduce the symptoms as well as the experience of the anxiety. Deep muscle relaxation is another example of a frequently used technique as well as biofeedback, meditation and yoga (Gillani & Smith, 2001). A common problem in reducing anxiety is that the anxiety itself conflicts with the coping strategy. For instance, the urge to slightly hyperventilate might be stronger than ones power to control ones breathing. Anxiety can also cause disruption in thoughts (Badger, 1994), so if one is trying to perform a relaxation exercise, thoughts can disrupt this process, and when people are not able to succeed this might cause more stress.

Because not everybody is able to achieve relaxation by him or herself, anti-anxiety drugs are available. A commonly prescribed variety is benzodiazepines (e.g. valium), preferably in combination with another strategy to cope with anxiety. A problem with long-term use of these types of drugs is that people often get dependent on them, creating another problem for the user.

2.4 Reducing Anxiety during an MRI scan

Philips and Deary (1995) reviewed several methods to reduce patient anxiety in MRI scans (see Figure 2). They divided the interventions into six main categories; environment and patient position, psychological preparation, hypnosis, aromatherapy, sedation, and screening patients for claustrophobia. For environment and patient position, a key element is to make the patient aware of the environment outside of the bore, this can be done through prism glasses, bright light at the end of the bore, air movement, a familiar person keeping company, but also open designs of the scanner can aid in this.

Figure 2. Traditional MRI scanning rooms.

Providing the patient with a 'panic' button is a way to increase the sense of being in control of the situation, which can reduce anxiety levels in patients undergoing stressful medical procedures (Philips & Deary, 1995). Badger (1994) suggested that regaining a realistic sense of control is important for a patient to cope with the situation. Another way to provide the patient with some control over their anxiety can be found in cognitive behavioral strategies such as breathing control, imagery and autogenic phrases (Lukins, Davan, & Drummond, 1997). Grey and colleagues suggest that the most powerful techniques to reduce anxiety are using a combination of both cognitive and behavioral strategies. Examples of this are prior imaginal rehearsal, relaxation training, graded exposure and cognitive reframing (Grey, Price, & Mathews, 2000). These can all be categorized under psychological preparation, as well as the strategies discussed in the previous section about reducing anxiety. A downside of cognitive training is that they have to be done in sessions with a professional, which takes a lot of time and often these sessions are also quite expensive. This is also the case for hypnosis, although often successful, it requires a trained hypnotist and a compliant trance susceptible patient. Furthermore, a quiet room is needed, as well as multiple hypnosis sessions.

Another interesting category is aromatherapy. Results of one study for example, suggested that heliotropin (a sweet vanilla-like scent) was associated with 63% less anxiety (Redd, Manne, Peters, Jacobsen, & Schmidt, 1994). However, other studies suggest that this anxiety reducing effect has to be attributed to a placebo effect (Ndao et al., 2010).

In severe cases of anxiety, patients are usually sedated (Edwards & Arthurs, 2011; Tischler et al., 2008). Disadvantages of this are that close patient monitoring is needed, and recovery time before they can leave the hospital (Murphy & Brunberg, 1997). Furthermore, side effects of the administered drug can occur.

Philips and Deary (1995) pointed out that lighting (e.g. bright light outside of the scanner) and air solutions (e.g. scent or ventilation), are simple and easily applied, not costly and not time consuming for the staff (Philips & Deary, 1995). Also videos are known to have a positive effect as a positive distractor. The solutions evaluated by Philips and Deary were still very basic, but seemed to be very appropriate in reducing anxiety in a simple fashion. These principles are already extended and applied in MRI systems by companies such as Philips and Siemens. Ambient systems of Philips make use of these environmental aspects, as well as the overall appearance of the room. They employed a clean design with rounded corners in the room, making the room appear more spacious. They allow the patient to choose a theme for the room. Depending on the theme, the color of the light changes, as well as projections and soundscapes (see Figure 3). This system has decreased the need for sedation in the Lutheran General Hospital with 16% in children under the age of eighteen and 28% in children under the age of four (Vaughan, 2009). Positive results were also found for the Healthcare Lighting of Siemens (see Figure 4). Dr. Tabesch reported:

> *"I used to work at a "normal" practice, where I always had two or three sedations each day. Here, almost all of our claustrophobic patients can make it through the procedure without sedation. Before, I often experienced cases where these kinds of patients just jumped right out of the unit – something that hasn't happened here"*

Figure 3 . Philips Ambient System MRI scanning room.

Figure 4. Siemens Healthcare Lighting MRI scanning room.

- Dr. Tabesch (Bludszuweit, 2009, p. 2)

The general impression is that when an ambient system is installed, also the medical staff prefer these rooms to work in, and patients have a better experience as well (Vaughan, 2009).

These results for the effects of ambient systems are based on single reports and small case studies, and are not published in a peer-reviewed journal, but from promotional material of the systems. However, the literature on the effects of Ambient Experience on patient anxiety is growing. The results of a recent study of Vogel and colleagues (Vogel et al., 2012) suggests that an audiovisual intervention in a PET uptake room lowered patient anxiety as measured by the STAI questionnaire, and decreased the uptake of the imaging liquid (FDG) in brown adipose tissue, resulting in clearer images in the PET scan. This suggests that offering a video with sound in combination with colored light in the room can indeed lead to serious advantages in healthcare.

Relaxation, whether reached through environmental aspects or anxiety coping strategies, is an important element of reducing anxiety and improving the patient experience.

2.5 Relaxation

Relaxation can be defined as "the state of being free from tension and anxiety" ("Relaxation," n.d.). Relaxation techniques are often used to calm anxious people.

Benson (1993) based his theory on the fight-flight response. Because of our fight-flight responses, one premise of relaxation is that one feels safe. Benson characterized the relaxation response by physiological changes such as a decrease in heart rate, breathing rate and muscle tension (Benson, 1993). Furthermore, relaxation promotes the release of the hormone endorphin in the body, which is known to relax tissue, reduce pain sensations and promote the feeling of well-being. Relaxation has no negative side effects, which makes it a very valuable technique to apply in the medical setting.

There are many ways to achieve relaxation; some are focused on coping with stress, while others focus on the relaxation itself. There are many different techniques, and there are several factors that can influence the successfulness of applying the technique. Smith's Attentional Behavioral Cognitive (ABC) Relaxation Theory states that the therapeutic effects of any relaxation technique are mediated by relaxation states, beliefs, dispositions, motivations and attitudes (Gillani & Smith, 2001). An important finding from their studies was that there are large differences among relaxation techniques with respect to the relaxation states that they evoke. For instance, they found that progressive muscle relaxation evokes disengagement and physical relaxation states, whereas breathing exercises and yoga stretching generally evoke energized and aware states (Gillani & Smith, 2001). These differentiations are especially important when comparing different relaxation techniques, because the same level of general relaxation can have different effects. One form of relaxation can energize, while another relaxation technique makes a person sleepy.

Rakel and Faass (2006) point out that many studies acknowledge the value of a variety of relaxation exercises. Examples of such exercises can be found in meditation, breathing and progressive muscle relaxation (Rakel & Faass, 2006). An important component of various stress reduction techniques is paced breathing, which refers to slow and deep abdominal breathing. Paced breathing is for example used in techniques such as meditation (Zeier, 1984), progressive relaxation (Bernstein & Borkovec, 1973), stress inoculation (Wells, Howard, Nowlin, & Vargas, 1986) and quieting response training (Ford, Stroebel, Strong, & Szarek, 1983). More about the paced breathing technique can be found in section 2.9.

2.6 Colored Light for Relaxation

The ambience in which a person is sitting can have an influence on the person's emotions and affect. This is of interest because the light color inside an MRI scanning room could help the patient to relax. For instance, Laufer and colleagues (2009) found that red light was more relaxing than blue light, which was generally perceived as activating (Laufer, Lang, Izso, & Nemeth, 2009). Results of Izso and colleagues (2009) suggest that a room with orange light (2700 K) of about 100 lx is experienced as having a relaxing effect (Izso, Lang, Laufer, Suplicz, & Horvath, 2009). Wan (2011) also found that orange light was preferred by the participants as a light setting to relax in.

Vogels (2008) also found that the more warm toned light settings were rated as more cozy than the ‘winter’ and ‘spring’ settings. This could indicate that warmer toned light, in this case orange, can increase the experienced coziness in the room, a factor that contradicts with elements such as tense, terrifying and restless.

In conclusion, it seems that the warmer toned colored light is experienced as relaxing.

2.7 Pulsating Light

Besides studies about the color and brightness of the light, there have been a few studies investigating the effects of pulsating light. Brandt (2010) investigated the ability to synchronize breathing with pulsating light in the environment. There was a condition in which participants were instructed to breathe along with the pulsating light, and a condition in which people were asked to relax. Results suggested that when people were asked to relax, the pulsating light induced stress, and people would not synchronize their breathing according to the light. When instructed to breathe along with the pulsating light rhythm, some could synchronize with the light rhythm, but not all participants were capable of doing so.

Wan (2011) investigated the effect of orange and white, static and pulsating light on relaxation. He found that people regarded the pulsating orange light as more pleasant than static orange light or pulsating and static white light. The outcomes of Wan’s study (2011) suggest that dynamic white light is experienced as stressful. In the experiment of Wan, the underlying principle of relaxation was based on a model of positive distraction and mimicking behavior of rhythmic actions. Wan (2011) did not ask the participants to breathe along with the pulsating light, and rather reasoned through the principle of distraction. Comparing these results with those of Brandt (2010), the finding that pulsating orange light can have a relaxing effect is promising. This would mean that even if people did not synchronize their breathing pattern with the presented pulsating light, they would still experience a relaxing effect.

2.8 Breathing

Since breathing is a central issue in this study, a bit more of the basic principles of breathing will be discussed. Breathing is a vital function which usually works under involuntary control, but can be switched to direct voluntary control as well (Ley, 1999). This is within certain limits, determined by involuntary controls such as a necessary oxygen intake (Ley, 1999). A slow breathing rate is an indication of a relaxed state, but the reverse could also be true, i.e. breathing slowly can elicit a relaxation response (Peng et al., 2004).

The primary function of breathing is obtaining oxygen, and emitting carbon dioxide from the body. The process of breathing is clearly described by Sherwood (2010): Filling the lungs with air occurs through pressure differences, caused by enlarging the chest cavity. A breathing cycle consists of: 1) Inhalation: contraction of the diaphragm. 2) Pause: Between the inhalation and exhalation, no air flows in or out of the lungs. 3) Exhalation: normally the exhalation is a passive event, occurring because the muscles relax which causes pressure, and as a result air flows out of the lungs. When breathing unconsciously, the body always looks for the path with the least resistance. For instance, when breathing unconsciously, one does not inhale until the maximum possible, but the maximum that can be achieved with the least effort. However, when one wants to breathe faster or extend the exhalation, this becomes an active process (Sherwood, 2010).

In a normal situation, an average adult breathes about 12 to 15 times per minute (Sherwood, 2010), with a range from 6 to 31 breaths per minute in adults (Benchetrit, 2000). Benchetrit (2000) pointed out that every person has an individual breathing pattern, to which she refers as '*personnalité respiratoire*'. Whether someone breathes regularly or irregularly can also be attributed to the breathing personality, results suggested that these patterns sustain in different situations and over a period of 4 years (Benchetrit, 2000). When designing for breathing coaching, this personal breathing pattern seems to be an important aspect to take into account.

2.9 Paced breathing

Paced breathing refers to slow and deep abdominal breathing, with a breathing frequency of 6 breaths per minute. At this frequency it elicits resonance in the body, enlarging its effect on relaxation (Vaschillo et al., 2006). It has shown to be successful in the treatment of panic attacks and hyperventilation syndromes (Clark, Salkovskis, & Cbalkley, 1985; Clark & Hirschman, 1990), as well as the reduction of anxiety states (Gilbert, 2003). Paced breathing is known to influence bodily responses like skin conductance level, muscle tension and heart rate (Zeier, 1984). Furthermore, it can result in heightened Heart Rate Variability (HRV), which is associated with relaxation and health (Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001; Peng et al., 2004; Vaschillo, Vaschillo, & Lehrer, 2006). The heart rate goes up during inhaling whereas heart rate goes down during exhaling. HRV is the difference between these two heart rate frequencies. When the HRV is in synchrony with respiration this is referred to as Respiratory Sinus Arrhythmia (RSA) (Rambaudi, Rossi, Mántaras, Perrone, & Siri, 2007).

Clark and Hirschman (1990) suggest that paced respiration training can be used to accomplish relaxation, but also to gain a sense of control over one's body. Eisen, Rapee and Barlow (1990) showed that paced breathing could result in a relaxation response. In this study participants were tested on relaxation in a meditation session. Half of the participants had to breathe at a rate of 10 cycles per minute and the other half at a rate of 20 cycles per minute. The participants in the slow paced breathing condition reported less subjective anxiety and more relaxation compared to the participants in the fast paced breathing condition (Eisen, Rapee, & Barlow, 1990).

Most people will have a breathing pace that is quite a bit higher than 6 breaths per minute, especially when not in a relaxed state, so it would require changing the speed of breathing. This is an active process, which can be done by for instance prolonging the exhalation. At first this might be difficult, but people can improve their ability to breathe in a slow pace substantially with a short training (Gavish, 2010; Parati et al., 2008; Rambaudi et al., 2007). Others regard breathing in a pace of 6 breaths per minute as something that most people can perform with very little training (Lehrer, Vaschillo, & Vaschillo, 2000).

2.10 Anxiety & paced breathing

As mentioned before, anxiety is linked to bodily and psychological responses. One of these responses of interest is increased breathing rate. Furthermore, when adrenaline rushes through the body, one can gain a heightened sensitivity to environmental stimuli and overall alertness to the point of decreased attentiveness, increased muscle tension, tremulousness and restlessness (Badger, 1994). More severe anxiety can cause shortness of breath and dizziness, but also disruption of thought processes (Badger, 1994). Shortness of breath and disruption of thought processes, are expected to interfere with the concentrated task to control ones breathing. The tension in the chest and abdomen can obstruct deep breathing, while worries can disrupt the concentration needed to follow a breathing guide or keep count.

Training breathing techniques, such as practicing or following classes in meditation, yoga or qi gong, can help in gaining more control over your own breathing. Furthermore, with practice it becomes easier to breathe in a slow pace. There are also devices and aids on the market that can help you train this. With device-guided breathing there is also the possibility to obtain feedback over ones performance.

2.11 Device Guided Breathing

Different modalities can be used to help people to breathe in a slow pace. In this section different cues that have been used before in either research or devices are discussed, such as sound, light, visualizations and biofeedback.

2.11.1 Sound

A traditional way to guide the breathing pace is by using an audible signal. The most basic form of this is a sound produced by an ordinary metronome, but also musical tones are used. A device that makes use of musical tones is the RESPeRATE device. The pitch of the tone guides the user to inhale or exhale, offering a respiratory rhythm. Interpreting the stimuli may be difficult because there is no way for the user to anticipate on the next tone.

Gavish (2010) investigated the effects of using the RESPeRATE® device as a self-treatment tool in the home setting (Gavish, 2010). Participants were using the device for 8 weeks, with 15-minute daily sessions. The treatment device worked by reducing breathing rates effortlessly by prolonging exhalation: patients were requested to synchronize breathing with the guiding tones, generated in response to the monitored breathing pattern by converting the signal into audible tones differentiated for inhalation and exhalation (Gavish, 2010). The participants had to learn how to use the device via self-learning from written instructions, and the device gave corrective messages about the participant's breathing when they failed to synchronize with the device, or when the sensor belt needed adjustment. Results suggested that participants followed the RESPeRATE device on average 68% (range 31-90%) of the time. However, the device was not always used correctly. Some people used the guiding tones as background music, while others fell asleep during the task.

2.11.2 Light

A more advanced aid is the ViMet, a device based on showing the desired breathing rhythm with an 8 LED bar, turning an increasing amount of LED's on to indicate the inhale and off to indicate the exhale (Rambaudi et al., 2007). Rambaudi and colleagues (2007) demonstrated that the study subjects were able to follow the linear light sequences at a speed of 12 breaths per minute, by keeping their respiration in synchrony with the imposed pattern. Participants were very well able to follow the device. An advantage of using the row of LEDs, is that the user has a clear beginning and end point, making it easier to predict when to inhale or exhale.

Another breathing guide design that incorporated light, but in the form of pulsating light, was the study of Brandt (2010). In contrast to the design of the ViMet, there was no clear beginning and end point, as she used pulsating light that varied in intensity. She investigated whether people were able to synchronize their breathing rhythm with the pulsating lights, and relax in this setting. The pulsating speed was fixed on a rate of 6,81 cycles per minute. Only three out of ten people were able to synchronize their breathing to the light setting. Furthermore, her results suggest that people only synchronize their breathing rhythm with the pulsating light when they are instructed to, and when not instructed people would breathe even faster.

2.11.3 Visualization

Pirhonen & Tuuri (2011) developed a combined visual with audio stimulus. In the design of the stimuli, Pirhonen and Tuuri (2011) made use of associations with the kinesthesia of breathing, principles of entrainment and the human capability of imitation. Kinesthesia refers to the awareness of the position and movement of the different parts of the body. This occurs through sensory organs (proprioceptors) in the muscles and joints. To allow for successful imitation, they pointed out that it is important to provide a continuous guide, not only at the turning points, where an inhalation transforms to an exhalation and vice versa, but using the different phases of the breathing cycle. To come to an intuitively understandable guide, they made use of patterns, which could be associated with specific aspects of the kinesthesia of breathing. These included (1) expanding and shrinking, which was supposed to be related e.g. to the chest movements, (2) ascending and descending, associated with the breathing cycle, the overall rise of tension and then release, (3) filling and emptying, associated with air flow to and from the body, (4) high and low flow rate, associated with current and pressure of air, (5) approaching and receding, associated with metaphorical expression of proximity: approaching in inhale, receding in exhale (Pirhonen & Tuuri, 2011). To make sure the point of maximum in- and exhalation could be predicted, a grey circle was used to present the user with borders, while the blue circle was used to represent the dynamics (see Figure 5).

The auditory characteristics were designed in a similar fashion, which resulted in sounds similar to beach waves, referring to the scheme of ascending and descending (corresponds to, e.g., rising level of muscle tension during the inhale and tension release during the exhale) and the scheme of flow rate. Higher volumes for faster movements and softer volume for slower movements were intended to correspond to the amount of airflow in breathing. The frequency spectrum of the tone expands during inhalation and shrinks during exhalation.

Figure 5. Screen shot of the animation used by Pirhonen and Tuuri (2011). The blue circle expands and shrinks over the grey area, indicating the in- and exhale respectively.

Unfortunately, in their user-test Pirhonen and Tuuri (2011) did not include measures of breathing synchronization. However, via questionnaires they did find that the participants experienced a strong calming effect from using the application.

2.11.4 Biofeedback

Awareness of one’s breathing is important when aiming for a behavioral change in breathing. One way to provide someone with self-awareness of breathing movements and compliance with the proposed rhythm is giving biofeedback. A standard definition of biofeedback was formulated in 2008 by the Association for Applied Psychophysiology and Biofeedback, the Biofeedback Certification Alliance and the International Society for Neurofeedback and Research (Biofeedback, 2011), which resulted in the following definition:

> *“Biofeedback is a process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brainwaves, heart function, breathing, muscle activity, and skin temperature. These instruments rapidly and accurately “feed back” information to the user. The presentation of this information – often in conjunction with changes in thinking, emotions, and behavior – supports desired physiological changes. Over time, these changes can endure without continued use of an instrument”.*

Meuret and colleagues (2001) investigated the use of respiratory biofeedback-assisted therapy in panic disorder. The device used in their study, generated rising tones to guide inhalation and falling tones to guide exhalation. This was presented at adjustable but predetermined rates (from 13 breaths/min in the first week gradually decreasing to 6 breaths/min in the last week) with a constant inspiration ratio of 0.4 (Meuret, Wilhelm, & Roth, 2001). The five treatment sessions (each 80 minutes) were spread over a 4-week period. After each session the participants received breathing training exercises to do at home, which were modified to personal needs. At home they were supported with biofeedback (PCO_2 and respiration rate). Meuret and colleagues reported that in general participants were able to follow the presented breathing rate, and found a considerable decrease in fear of anxiety symptoms, and panic attack frequency and severity, for people who were following this breathing training. Furthermore, they identified the feeling of control as a contributor to this effect (Meuret, Wilhelm, Ritz, & Roth, 2003).

Research by Schein and colleagues (2001) investigated the effects of training paced breathing over a period of 8 weeks with a daily session of 10 minutes. During the session participants used either a biofeedback device that aimed at slow and regular breathing (breathing measured by a belt type respiration sensor) or listened to quiet music. Their results suggest that lowering the breathing frequency by giving exercises to do at home can have beneficial long term effects in reducing blood pressure (Schein, Gavish, Herz, Naveh, & Knishkowy, 2001).

A practical issue of using biofeedback, is that sensors are needed, and signals need to be represented in an easy to understand way. Technologies are rapidly developing, and more wearable designs are being made for sensors, for instance by incorporating the sensors into a watch[1].

2.11.5 Conclusion about Device-Guided Breathing

It seems that for all representations aimed to guide breathing, it is important to provide easy to understand cues. It is important that the cue for the full inhalation and exhalation is clear, intuitive and allows the user to anticipate.

It seems that training with the device helps to increase the ability to follow the imposed breathing pace, as longitudinal studies find improvements over time in breathing performance.

Furthermore, clear instructions for the use of the device are needed. It might be better to demonstrate the device, or give verbal explanations instead of giving written instructions. Biofeedback is a good way to provide understanding and stimulation for someone to keep to

[1] An example of this can be found on the following website: http://www.trendhunter.com/trends/biofeedback-stresswatch (“Stress-Sensing Watches,” n.d.).

the schedule of practicing paced breathing. However, in some cases this type of information might be too much to handle. It is very useful in the training process, but if applied during stressful situations, such as during an MRI scan, it could cause the patient to feel more stressed, as they are less likely to perform well all the time. Negative feedback could have a demotivating effect.

2.12 Theoretical Model

Pulsating orange light is suggested to have a relaxing effect (Wan, 2011), this effect might be increased when paced breathing is applied as well. Therefore this study investigates the effect of breathing with pulsating orange light on reducing anxiety. Furthermore, the pulsation of the light in this study will adapt to the participant's breathing rate, and the way the light pulsates will be adapted to the breathing curve. These aspects are expected to make it easier for the participant to follow the light, and to make the association with breathing.

It is hypothesized that pulsating light can be a technique to cope with anxiety and the associated stress (see Figure 6). When being able to control their breathing, one can gain a sense of being more in control of the situation, which changes the way one appraises the stressful or threatening situation. Furthermore, by adapting the breathing frequency to a low pace, one of the physiological anxiety symptoms is directly influenced, which in turn influences other symptoms of anxiety. This is expected to directly influence the state anxiety of a person. This all together would result in state anxiety reduction.

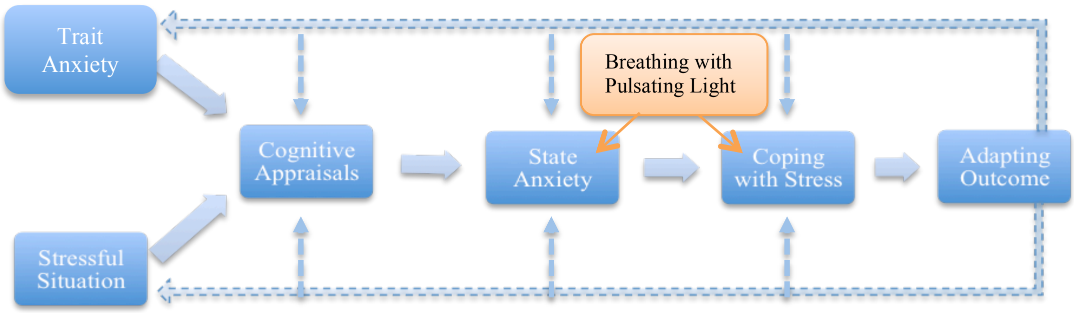


Figure 6. Theoretical model of the pulsating light inervention.

2.13 Aim and Hypotheses

Earlier research suggested that external cues such as sound could be used to guide breathing, however, for many existing solutions it remains hard to anticipate for the maximum inhale and exhale. For a breathing guide inside the MRI scanner, the loud noise made by the MRI scanner itself could interfere with audible cues. For this specific case, another modality would be more appropriate. Pulsating light has shown promising results to function as a method to achieve relaxation and function as a breathing guide, but the current literature does not provide enough evidence for an application to reduce anxiety. Especially the ability to follow pulsating light as a guide is an issue.

The aim of this study is to verify whether pulsating light could be an appropriate way to guide patients into a predictable, slow breathing pace, for the purpose of reducing anxiety. Furthermore, the role of anxiety in the ability to follow the light with ones breathing will be studied.

The following research questions and hypotheses were tested:

Q_1: What is the effect of lowering the breathing frequency, using pulsating light as a breathing guide, on anxiety levels?

Q_2: What is the effect of higher levels of anxiety on the ability to synchronize one's breathing with the pulsating light?

Q_3: What is the effect of anxiety on the number of squeezes in the haptic interface?

Hypothesis for the pilot test:

H_1: We expected that anxiety levels would be higher after a relaxation period of 8 minutes, when *no breathing guide* is presented, for participants that were more anxious at the beginning of the relaxation period.

$H_{2.1}$: It was expected that participants would squeeze more often in the haptic interface when experiencing more anxiety.

Hypotheses for the experiment:

$H_{2.2}$: It was expected that participants would squeeze more often in the haptic interface when experiencing more anxiety.

H_3: We expected that participants were able to follow the pulsating light with their breathing, such that the pace of breathing does not differ more than half a breathing cycle per minute from the pulsating frequency in breaths per minute of the light.

H_4: Based on the current literature we expected that it would be harder for participants who were more anxious to lower their breathing pace by following the pulsating light than for non-anxious participants. The symptoms of anxiety are expected to have a negative effect on the ability to follow the light with one's breathing, as measured by the deviation of the breathing from the presented pace by the pulsating light.

H_5: It was expected that people who were anxious would start the breathing exercise at a higher breathing rate than the control condition, because a heightened breathing pace is one of the symptoms of anxiety.

H_6: Based on the current literature we expected that lowering the breathing pace, by following the pulsating light with one's breathing, would reduce anxiety levels.

H_7: We expected that anxiety levels would reduce after breathing with the pulsating light, such that the anxiety levels would be the same for people who started the breathing exercise with higher levels of anxiety as those who started this exercise at lower levels of anxiety.

3 Pilot Test

3.1 Method

A pilot test was conducted to check whether the film clips were a good manipulation, and to see how anxiety levels reduced in the two conditions. The experiments were conducted in June of 2012, during working hours.

3.1.1 Participants and Design

All participants (n = 22) were Dutch female students, ages ranged from 18 to 26 (M = 22.73, SD = 2.07). An experiment was performed following a 1 (relaxation) x 2 (anxiety induction vs. no anxiety induction) between groups design. Participants were recruited via a participant database, flyers and directly asking whether people were willing to participate. Participants received €7.50 for their participation.

3.1.2 Setting and Apparatus

The pilot test was conducted in one of the labs at the IPO building of the Eindhoven University of Technology (see Figure 7). The experimenter was in the same room as the participant, separated by two panels.

Dimmed light from luminaires in the ceiling was present (80 lx on the working area). There was no natural light present in the room.

Figure 7. General Purpose Lab, IPO building at Eindhoven University of Technology

3.1.3 Manipulation

To induce anxiety, validated film clips were shown. During the experiment, participants watched a sequence of film clips (duration approximately 8 minutes), which consisted of either anxiety-inducing or neutral movie clips. All movie clips were from a validated database, created by Schaefer and colleagues for the anxiety inducing clips (Schaefer, Nils, Sanchez, & Philippot, 2010), and the database created by Hewig and colleagues for the neutral clips (Hewig et al., 2005). The neutral film clips were taken from another database than the anxiety inducing film clips, because the neutral clips in the database of Schaefer and colleagues were all from French speaking movies, while the anxiety inducing film clips were from English speaking movies. Since the anxiety inducing film clips were longer in duration, the two longest neutral film clips were repeated, resulting into the following film fragment sequences, both having durations of approximately 8 minutes, see Table 1.

Table 1. Film clip sequences of the two conditions.

Anxiety-inducing movie fragment sequence (8'31'')	Neutral movie fragment sequence (8'00'')
The Blair Witch Project (4'05") Final scene in which the characters are apparently killed.	***Hannah and her sisters (1'33")*** Hannah and Holly go shopping. They are talking about last night.
The Shining (4'26") The character played by Jack Nicholson pursues his wife with an axe.	***The Last Emperor (1'23")*** The young heir of China meets the British teacher who has been assigned to him. They are talking about the lessons.
	All the President's Men (1'5") Bob is a reporter and writes about a court case. Meanwhile, during the hearing he asks one of the attendees what had just happened.
	Crimes and Misdemeanors (1'3") Judah and Jack are walking through an autumnal garden. They are talking about last night's football match.
	Hannah and her sisters (1'33") Hannah and Holly go shopping. They are talking about last night.
	The Last Emperor (1'23") The young heir of China meets the British teacher who has been assigned to him. They are talking about the lessons.

3.1.4 Measures

To measure anxiety we used the State-Trait Anxiety Inventory (STAI) and the Differential Emotions Scale (DES) questionnaire. Additional questions were asked in the final questionnaire, see 12 Appendix A: Questionnaire. Furthermore, physiological measures were used as measures for anxiety being; skin conductance, breathing rate, heart rate and muscle activity. In the physiological measures a heightened breathing pace, increased heart rate, increased skin conductance, and lower heart rate variability can characterize anxiety. These measures are common measures for anxiety.

Besides the common measures, also a new measure was used in the form of a haptic interface, in which participants could squeeze to indicate their anxiety level. This was used as a continuous measure for anxiety during the film fragments.

3.1.4.1 Questionnaires

Several questionnaires were included. Anxiety was measured by means of the State Trait Anxiety Inventory (STAI) (see 3.1.4.1.1). Emotion elicited by the film fragments was measured by means of the Differential Emotional Scale (DES) (see 3.1.4.1.2). Furthermore, participants were asked about their experience with the pulsating light in order to gain a better understanding as to what could be changed to improve the breathing guide. For the complete questionnaire please see 12 Appendix A: Questionnaire.

3.1.4.1.1 STAI

The State-Trait Anxiety Inventory (STAI) was developed by Spielberg and colleagues (Spielberger et al., 1970). In the current study we used the shortened 8-item STAI version, validated by Knippenberg and colleagues (van Knippenberg, Duivenvoorden, Bonke, & Passchier, 1990). The shortened version was used, because administering the long version would make the experiment very long. Furthermore, with time the effect of the anxiety manipulation could decrease. For the STAI-T, a 4-point Likert scale ranging from 1 (*almost never)* to 4 *(almost always*) was used. For the STAI-S, a 4-point Likert scale ranging from 1 (*not at all)* to 4 *(very much)* was used. The STAI-T refers to the general tendency of a person to get stressed or anxious, the STAI-S refers to the state of the person in a particular moment. STAI values can range from 20 to 80, with low scores indicating low anxiety and a high score indicating high anxiety. The positive items on the STAI were rotated, and then the scores on all 8 items were added. The STAI scores were converted to the 20-item version by multiplying the score with 2.5. Using this methodology, we were able to construct a reliable measure for state anxiety (STAI-S, $\alpha = .762$), but not for trait anxiety (STAI-T, $\alpha = .168$).

3.1.4.1.2 DES

The DES questionnaire was used at the end of the experiment. The DES questionnaire was used, which was originally described by Izard and colleagues (1974) and later modified by McHugo and colleagues (1982). With the DES we asked about the emotions the film clips elicited, using 10 items, which were measured on a 5-point Likert scale (1 = *"not at all"*, 5 = *"very intense"*). The DES consists of two factors, a positive composite score and a negative composite score.

The was used in the study of Schaefer and colleagues (2010), and repeated here to see if the neutral film clips from the database of Hewig and colleagues would also be classified as neutral on this scale, and if we could again classify the anxiety inducing film clips as anxiety inducing.

The DES questionnaire was translated in Dutch and simplified by reducing the describing emotions to one instead of three. A translation was made that best fit the three descriptions, and a colleague checked the translated version. We were able to construct a reliable measure for the DES ($\alpha = .641$). However, only the negative composite score ($\alpha = .826$) was reliable, the positive composite score ($\alpha = .587$) wasn't.

Additionally, self-reported emotional arousal was included ("How strong was the emotion that the movie elicited?") with a 10-point scale with 1 representing "no emotion at all", and 10 "the strongest emotion ever experienced".

3.1.4.1.3 Atmosphere

Another element of the questionnaire was about the environment (atmosphere questionnaire of Vogels, 2008), which consisted of 38 items measured by means of a 5-point

Likert scale. The 38 questions have two factors, coziness and liveliness (Vogels, 2008). We were able to construct a reliable measure for the positive factor (α = .93), and the negative factor (α = .89).

3.1.4.2 Physiological measures

All physiological measures were recorded using a NeXus-10, with a sampling rate of 1024 Hz in the experiment. For the analysis of the physiological data, averages were taken over 1 minute at 13 different points in time. The first epoch was taken during the baseline, the minute was taken from 70 to 10 seconds before the end of the baseline measurements. There were 6 epochs taken during the film clips, the first epoch during the film clips started one minute after the film clips started. Than for each minute following, another epoch was set, for a total of 6 epochs (epoch 2 -7). The same procedure was applied to the relaxation period, the first epoch started one minute after the relaxation period had started, and for each minute following, an epoch was set, for a total of 6 epochs (epoch 8 – 13).

Multiple moments in time were chosen to have a better understanding of the changes over time, and to be able to see whether for instance the beginning of the anxiety inducing film clips sequence induced more anxiety than the end of the sequence. Breathing

The breathing pattern of the participant was measured using a breathing belt, which was placed just underneath the ribs. For the analysis of the breathing data a Butterworth IIR digital filter was applied as well as a low-pass filter. The minimum and maximum size of the peak was determined by hand to prevent detecting too many or not enough peaks. Some data had a lot of variation in the amplitude of the peaks.

3.1.4.2.1 Skin Conductance (SC)

Skin conductance was measured by placing two electrodes on the hands of the participant as depicted in Figure 8. A higher skin conductance is associated with higher arousal and stress. The skin conductance signal was normalized on the baseline, using the following formula:

$$SC_{normalized} = (SC - M_{Scbaseline}) / SD_{SCbaseline}$$

Skin conductance levels were taken as measure of anxiety, in which increase in value indicates an increase in anxiety.

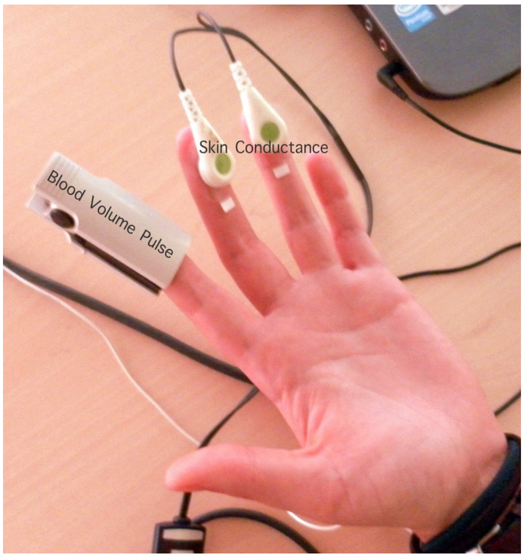


Figure 8. Example of how the BVP and SC sensors were connected.

3.1.4.2.2 Blood Volume Pulse (BVP)

Blood volume pulse was measured to be able to monitor the heart rate of the participant. The peaks were detected by loading typical waveforms (see Figure 9) of the BVP signal into Matlab, adjusted to the sampling frequency of the BVP signal. A high-pass and a low-pass filter are applied to the data to de-trend the signal and remove noise from the signal. From the peak detection inter-beat intervals (IBI's) were calculated. These were used to calculate the heart rate and the heart rate variability (HRV) through fast Fourier transformation (FFT), in the high frequency bands. More heart rate variability indicates more relaxation.

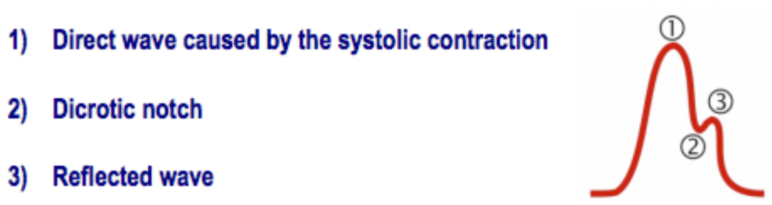


Figure 9. Blood volume pulse, typical waveform. From D. C. Combatalde (2010).

3.1.4.2.3 Electromyogram (EMG)

Muscle tension was measured using electrodes placed on the forearm. Increased muscle tension is taken as an indication for increased anxiety. A low-pass filter of 20 Hz, and a noise filter of 50 Hz were applied. For each second the muscle activity is calculated from the EMG signal, using a time frame of 1 second.

3.1.4.3 Haptic Interface

The haptic interface (see Figure 10, as described and validated by Horst (Horst, 2012), was used as a continuous measure for anxiety. To indicate their anxiety level, participants could squeeze the haptic interface. The number of the squeezes was used as a measure of anxiety. The data from the haptic interface was wirelessly received with a sampling frequency of 22.13 Hz. A peak was defined as follows: The signal had basically two types of peaks, very clear short squeezes, which had a clear signal, and more ambiguous peaks. The typical peaks (see Figure 11) were counted, ignoring the stabilization peaks of the signal after the main peak. For the ambiguous peaks, a threshold was set on an increase in signal larger than 100 (range = -8000 – 8000). The number of peaks was corrected using the EMG signal, peaks without corresponding EMG activity were removed as described by Horst (2012).

Figure 10. The haptic interface.

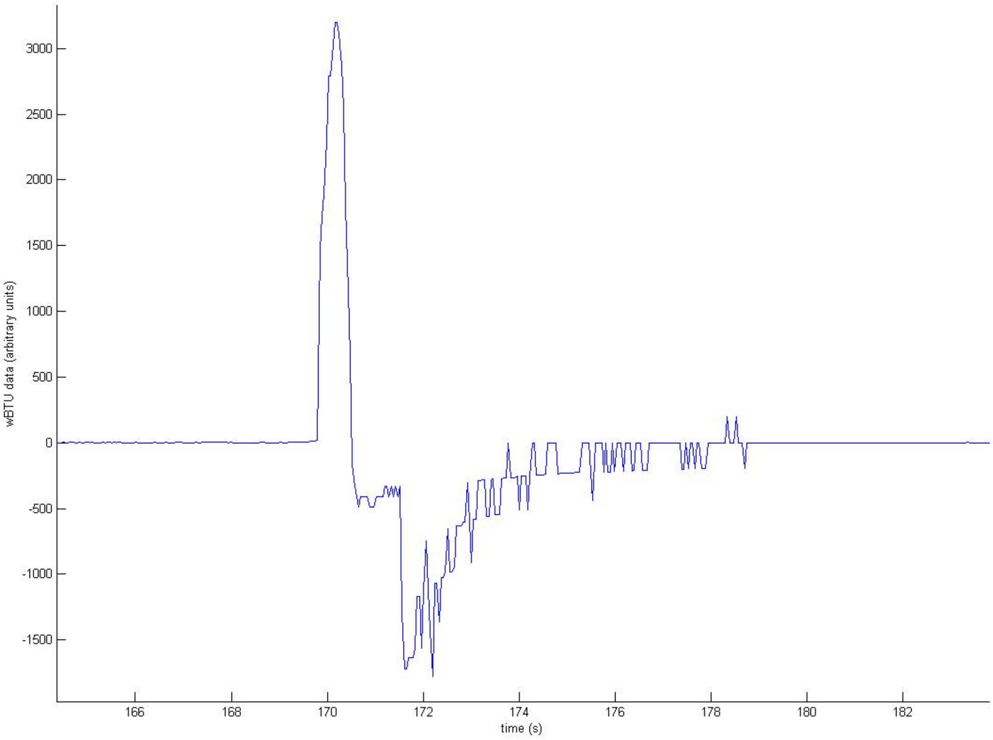


Figure 11. Typical wBTU peak.

3.1.5 Procedure

The participants were asked to sit behind a table where they were briefed about the experiment, and signed an informed consent form. The participants were notified that the film clips that were shown during the experiment could be scary. A short instruction about the haptic interface followed and a demonstration on how to hold and squeeze the haptic interface was given. In this instruction participants were asked to indicate if they were feeling anxious by squeezing the haptic interface during the film fragments, they were instructed that they could squeeze as hard and as often as they wanted. The sensors to measure the physiological data were already connected to the measuring device (NeXus), and after the briefing attached to the participant. Then a check was performed to see if all sensors were connected correctly. If all signals came through correctly, the experiment started. Participants used headphones to listen to the sound that came with the film clips.

The first task was to watch an aquatic movie for 5 minutes, to enable baseline measurements. After this first task, the participant was asked to complete the shortened 8-item STAI-T and STAI-S. All questionnaires were filled in on the computer using the free student services of www.surveygizmo.com. After the STAI questionnaires, written instructions were presented for the second task, to motivate the participant to keep watching the clips, this instruction also stated that questions would be asked about the film clip sequence that was about to start. Furthermore, as a reminder, they got written instructions about how to use the haptic interface. The experiment leader came over and asked the participant to hold the haptic interface, and then started the film clips. Participants were presented with a sequence of film clips that were either anxiety inducing or neutral (duration of approximately 8 min). The experiment leader returned after the movie sequence ended, and asked the participant to lay down the haptic interface. The experiment leader then reopened the web browser with the STAI-S. After participants completed the STAI-S for the second time, they received written instructions about the third task. The third task was a relaxation task (duration of 8 min). Participants were asked to relax as good as possible, and told that they would be notified when they could proceed to the last questionnaire. Finally, the STAI-S was administered for the third time together with the DES and questions about the film clips. The total duration of the experiment was 45 minutes (see Table 2).

Table 2. Schedule of the different elements of the experiment and their durations.

Duration	Control condition	Experimental condition
5 min	Briefing & attaching sensors	
5 min	Baseline measurement	
2 min	STAI-S & STAI-T	
8 min	Neutral film clips & Haptic Interface	Anxiety Inducing film clips & Haptic Interface
2 min	STAI-S	
8 min	Relaxation period	
10 min	STAI-S & Final Questionnaire	
3 min	Detaching sensors	

4 Results Pilot Test

4.1 Manipulation Check

It was expected that the participants in the experimental condition would experience more anxiety than participants in the control condition after watching the film clips. Results of a t-test on STAI-S levels directly after watching the film clips, suggested that participants in the experimental group indeed reported more anxiety (*M* = 35.23, *SD* = 6.37) than participants in the control group (*M* = 29.09, *SD* = 4.37), t(20) = -2.64, *p* = .02).

It was expected that the participants in the experimental condition would experience more negative emotions than participants in the control condition. Since the positive emotion factor was not found to be reliable, we only investigated the negative emotion factor. In line with our expectations, participants in the experimental condition experienced more negative emotions (*M* = 2.546, *SD* = .578) than those in the control condition did (*M* = 1.333, *SD* = .365), *t*(20) = -5.882, *p* < .001.

To zoom in on the emotions that are most relevant for this study, we investigated the questions in the DES that asked to what extent the film clips elicited anxiety and tension. Results suggest that in the control group less anxiety and tension was elicited by the film clips ($M_{anxious}$ = 1.27, M_{tense} =1.91) than in the experimental group ($M_{anxious}$ = 3.55, M_{tense} =4.18), $t_{anxious}(18.97) = -7.22$, $p < .001$, $t_{tense}(17.00) = -6.73$, $p < .001$. This can also be seen in Figure 12.

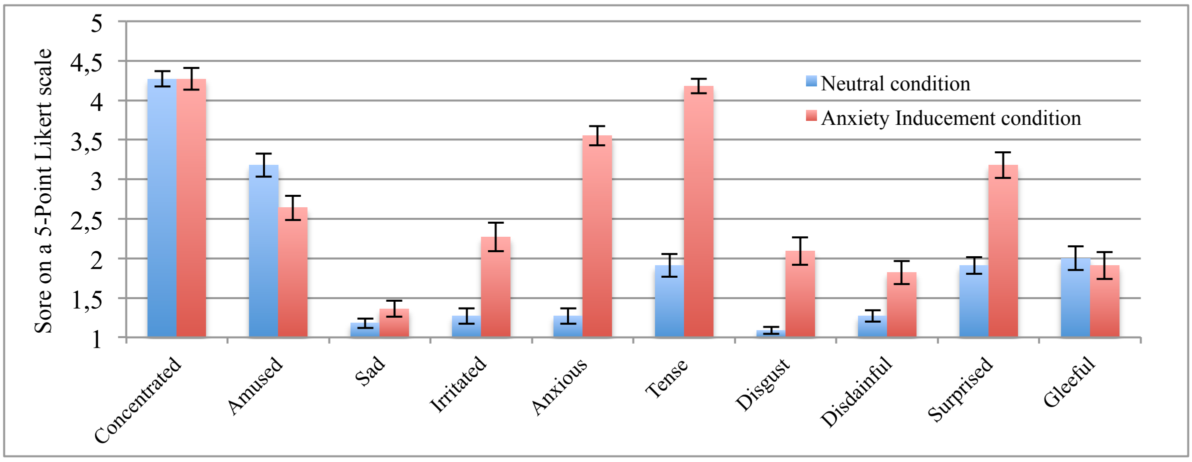


Figure 12. Results from the question: To what extend did you extend did you experience the following emotions during the film clips? Error bars indicate standard errors.

The neutral films were not supposed to strongly induce any kind of emotion; this was also reflected in the self-reported arousal item that was answered on a scale from 1 (no emotion at all) to 10 (the strongest emotion ever experienced). Participants in the control condition reported less emotion induced by the film clips (*M* = 2.82) than the participants in the experimental condition (*M* = 6.45), *t*(19.98) = -7.43, *p* < .001. Furthermore, the control group responded that the only emotion it elicited was concentration, and slight amusement.

4.2 Anxiety levels after a relaxation period

To test how the anxiety levels changed over time as a result of watching film clips and a relaxation period, a repeated measures ANOVA was performed, with STAI-S values as repeated measure and condition as a between subject factor.

Confirming our first hypothesis (H_1) that participants who were more anxious when starting the relaxation period without pulsating light, would also report more anxiety after the relaxation period than participants who started the relaxation exercise at a low anxiety levels, results suggested that participants in the experimental condition indeed reported more anxiety (M = 32.05, SD = 4.45) than the participants in the control condition (M = 25.45, SD = 4.85) after the relaxation period, F (1, 20) = 10.30, p < .01. Furthermore, participants decreased anxiety during the relaxation period in both the control condition (M = 25.45, SD = 4.85) and the experimental condition (M = 32.05, SD = 4.45), compared to the anxiety levels experienced after watching the film clips by participants in the control condition (M = 29.09, SD = 4.37) and in the experimental condition (M = 35.23, SD = 6.37), (F(2, 40) = 3.546, p = .04).

As can be seen in Figure 13, participants in both groups reduced anxiety during the relaxation period, but the difference induced by the film clips sustained.

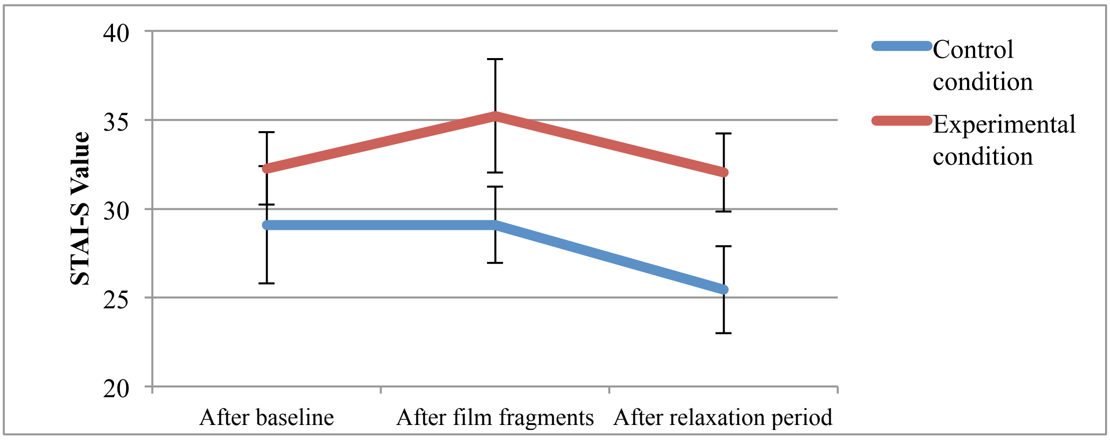


Figure 13. Differences between conditions on the STAI-S scores on different moments in the experiment. The error bars depict the standard deviation.

4.3 Physiological responses to the conditions

Unfortunately there was some missing data during the physiological measurements; the loss of signal was systematically 2 or 19 data packages, randomly occurring over time. The same durations of the missing data denotes interference with another device. Probably, the wBTU device, which was used for the haptic measure, interfered with the Nexus device, since both used a wireless signal to send data. The distortions did not occur in the same amount for all participants. Participants with timings between the markers that were too short were excluded from the analysis. Furthermore, for the skin conductance data, values were interpolated over the times where data was missing; this was considered acceptable since skin conductance has a slowly changing course.

4.3.1 Skin Conductance

To clear the data from strange peaks, three participants who had been sneezing throughout the experiment were removed form the analysis. It was expected that participants in the experimental condition would show a higher skin conductance level. When looking at the raw skin conductance data (see Figure 14), participants in the experimental group systematically had higher skin conductance values than participants in the control group. This suggests that the participants in the experimental group experienced more anxiety, this data corresponds well with what we found on the STAI-S scores. It was expected that the experimental condition would show higher levels of skin conductance during the film clips (epoch 2-7), results of a repeated measures ANOVA with averages the periods of the baseline, film clips and relaxation as repeated measure and condition as between factor, suggested that there was no effect of condition, $F(1, 14) = 1.16$, $p = .30$. Furthermore, increases in skin conductance during watching the film clips were found for both the participants in the control condition ($M = 2.79$, $SD = 2.43$) as for participants in the experimental condition ($M = 3.98$, $SD = 2.08$) compared to the baseline of participants in the control condition ($M = 1.51$, $SD = 1.84$) and the participants in the experimental condition ($M = 2.30$, $SD = 1.66$), $F(2, 28) = 10.65$, $p > .01$. For both conditions, no changes were found when comparing the average skin conductance during watching the film clips and the relaxation period. The hypothesis that the participants in the experimental condition had higher skin conductance values during the watching the film clips has to be rejected.

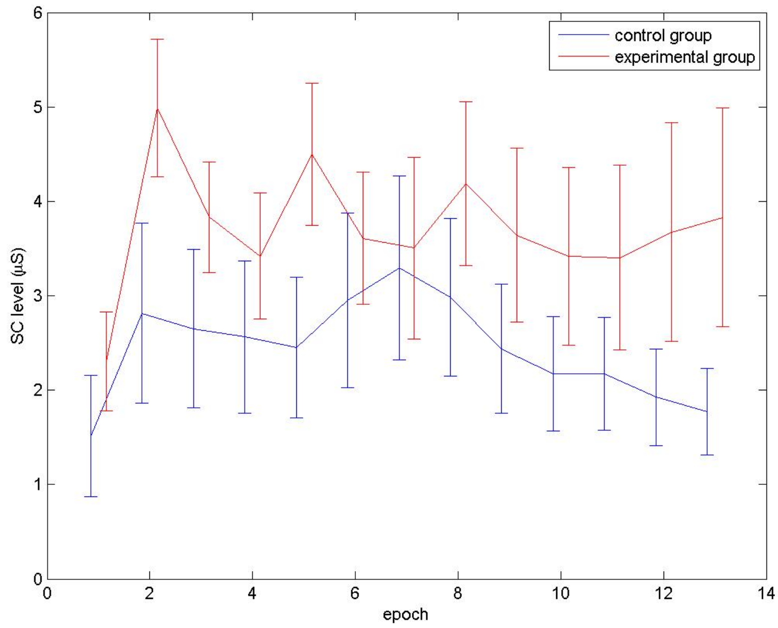


Figure 14. Skin conductance levels, represented in groups over time. Averages over a period of 1 minute; epoch 1 = baseline, epoch 2-7 = film fragments, epoch 8-13 = breathing period. Error bars represent the standard errors.

Due to large variations in the baseline, the normalization on the baseline did not provide the correct overview. Therefore, the skin conductance data was plotted on a logarithmic scale, as can be seen in Figure 15. This suggested that the two conditions did not differ in skin conductance during the whole experiment. Although the two peaks as a result of watching the two anxiety inducing film clips are relatively large, the participants in the experimental group reduced more skin conductance than that they increased. The participants in the control condition raised their skin conductance level at the point that the film clips started that were shown for the second time. Although nobody reported to mind the fact that two film clips were repeated, the data showed a slight increase in skin conductance levels. Furthermore, this data shows that both groups reduced skin conductance during the relaxation period.

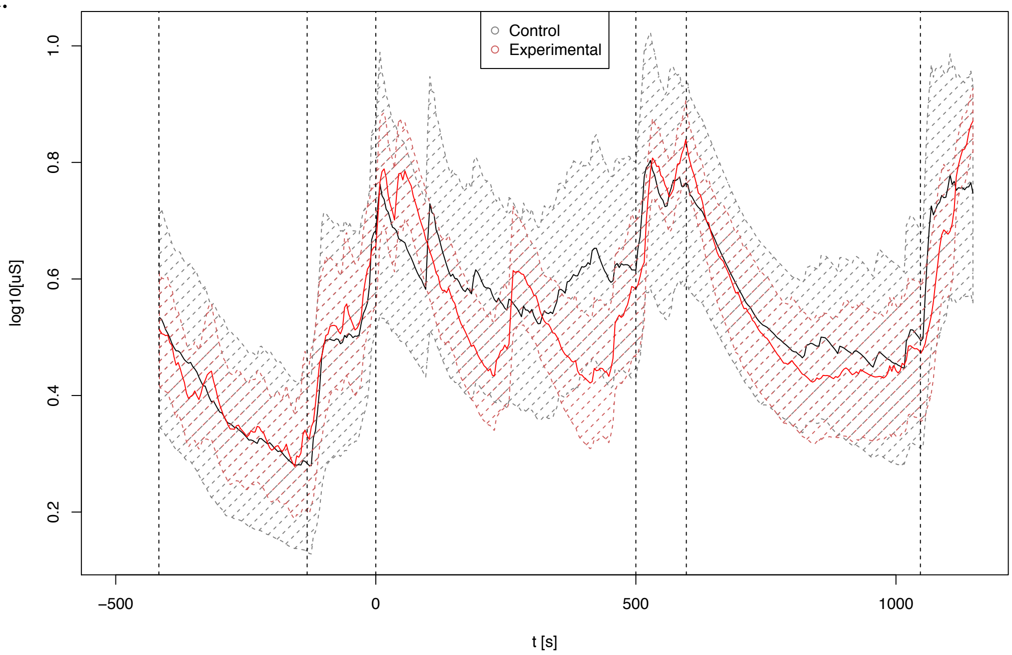


Figure 15. Skin conductance of the two conditions on a logarithmic scale, the dashed area represents the standard error. The first period represents the baseline, the second the questionnaire, the third watching the film clips, the fourth a questionnaire, the fifth a breathing period, and last the final questionnaire. In this plot, the timings are adjusted to the average, to be able to compare the participants in the same task.

4.3.2 Heart rate (measured with ECG)

The InterBeat Intervals (IBI), depicted in Figure 16, had large variations. It was expected that the experimental condition would have an increased heart rate compared to the control condition during the film clips (epoch 2-7). No difference was found between groups in terms of heart rate, $F(1, 18) = .00$, $p = .95$. Also no differences were found over time in heart rate from the average heart rate during watching the film clips to the average heart rate during the relaxation period, $F(1, 18) = 1.30$, $p = .27$.

The fact that there was missing data, lead to missing peaks in heart rate, therefore the data was considered unreliable for heart rate variability analysis.

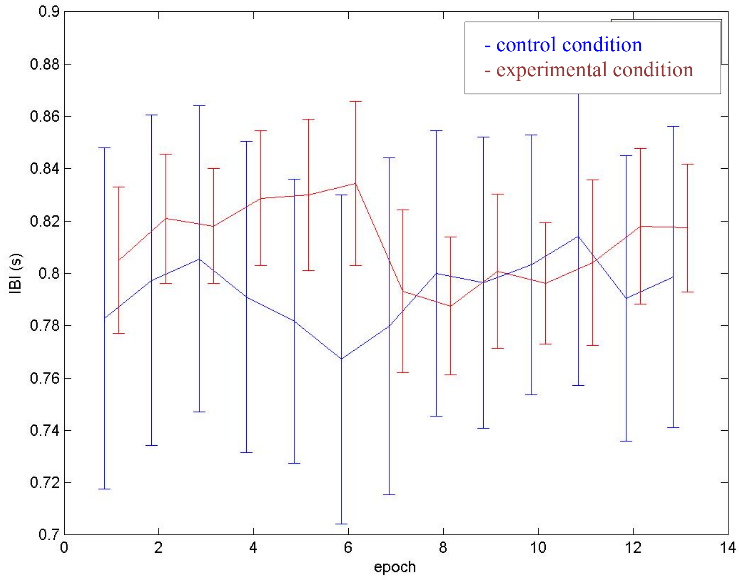


Figure 16. Heart rate of the two groups over time, as calculated from the ECG signal. Averages over a period of 1 minute; epoch 1 = baseline, epoch 2-7 = film fragments, epoch 8-13 = breathing period. Error bars represent the standard errors.

4.3.3 Breathing

Since the data of the two conditions were quite close together in the end of the experiment (see Figure 17) the breathing data were not normalized.

In line with our expectations that participants who watched the anxiety inducing film clips would show higher breathing rates during watching the movie, results suggest that participants in the experimental condition did not increase breathing rates during watching the film clips (epoch 2 – 7) (M = 18.60, SD = 1.43) compared to the baseline (M = 17.50, SD = 3.20), $F(2,36) = 10.25$, $p < .001$. During the relaxation period, participants in the experimental condition lowered their breathing rate (M = 14.90, SD = 3.57). In the control condition, no differences were found over time.

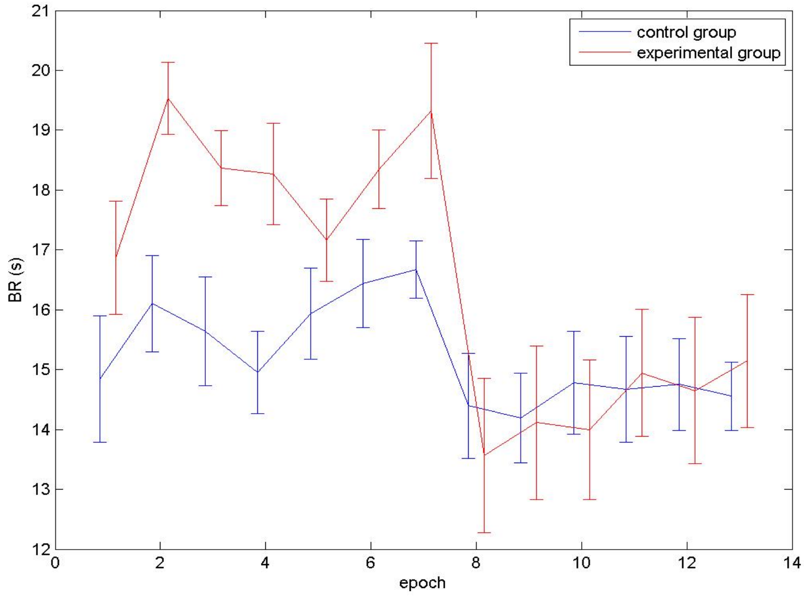


Figure 17. Breathing rates of the two groups at different moments in time over a period of 1 minute; epoch 1 = baseline, epoch 2-7 = film fragments, epoch 8-13 = breathing period. Error bars represent the standard errors.

4.3.4 EMG

The EMG sensors were not placed precise enough, and too much data was missing due to lost connections during the measurements, and potentially due to interference with the wBTU. In the future, the cables of the sensors should be placed differently, such that the participant can complete the questionnaires without disturbing the EMG sensors. Furthermore, it is important to clean the skin very well before applying the sensors; this increased the quality of the signal.

4.4 Responses on the haptic interface

The data of the haptic interface as retrieved from the wBTU were used to assess anxiety levels. Because EMG data was considered not reliable, the measure was not corrected as described by Horst (2012).

In line with our hypothesis ($H_{2.1}$), that participants in the experimental condition would have squeezed more often than participants in the control condition, results suggested that indeed the participants in the experimental group squeezed more often (M = 1.90, SD = 1.73) than the participants in the control group (M = .00, SD = .00), $t(19) = -3.66$, $p < .01$. The haptic measure also correlated with the scores on the negative emotion factor of the DES questionnaire ($r_s = .62$, $p < .01$), but not with the scores on the STAI-S questionnaire administered directly after watching the film fragments ($r_s = .39$, $p = .08$).

5 Discussion Pilot Test

We expected that the anxiety inducing film clips would induce anxiety. In line with our expectations, results of the DES scores did show that the people who watched the anxiety inducing film clips reported to have experienced significantly more negative emotions, such as anxiety and tension, while watching the film clips. Differences between groups in STAI-S scores were found both after watching the film clips as after the relaxation period. In line with our expectations, this suggests the effect of the anxiety induction sustained after a relaxation period of 8 minutes.

In the experiment we will investigate whether lowering the breathing frequency, using pulsating light as a guide could help the participants in the experimental condition to relax.

6 Experiment

6.1 Method

The aim of the experiment is to see whether pulsating light can be used to guide people into slow paced breathing, and to find whether this results in a relaxation response. A comparison between the ability to follow the light is made between people who were in the anxiety induction condition and people who were in a neutral condition. Furthermore, we want to investigate if higher levels of anxiety will result in a higher number of squeezes in the haptic interface.

6.1.1 Participants & Design

All participants (*n* = 42) were Dutch female Philips employees or interns, ages ranged from 22 to 56 years (*M* = 32.33, *SD* = 11.36). An experiment was performed following a 1 (breathing with pulsating light) x 2 (anxiety induction vs. no anxiety induction) between groups design. Participants were recruited via posters, by directly asking whether people were willing to participate, and through an email to all secretaries. Participants were not paid for their participation.

6.1.2 Setting & Apparatus

The experiments were conducted in one of the labs at Philips Research on the High Tech Campus in Eindhoven (see Figure 18). The experimenter was present in the same room as the participant, separated by room dividers (see Figure 19). A laptop was used to show the film clips and to complete the questionnaires. Two NeXus devices were used as well as the wBTU with the haptic interface.

Figure 18. Lab space with participant, at Philips Research

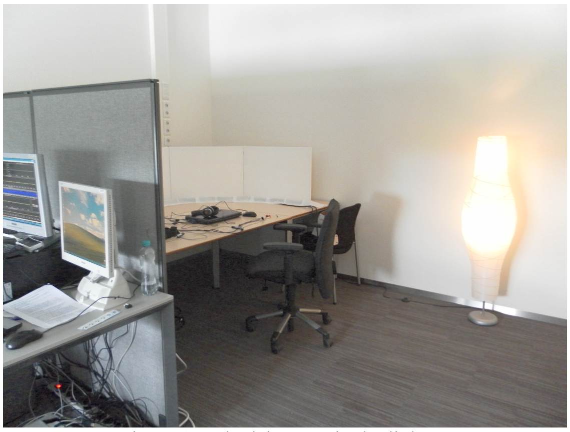


Figure 19. The lab space in daylight.

6.1.2.1 Light settings

Following the previous research of Wan (2011) and Izso and colleagues (2009) orange light was chosen. The light was projected on panels with a low illuminance.

Ten Philips iColor Cove MX Powercore luminaires were used, each consisting of 18 LED's, which were placed in such a way that they surrounded the participant. Five canvas panels of 40x60cm were used to project the light on, forming a 3-meter long curve placed over a width of 1m80. The LED's were controlled with a DMX controller. The maximum illuminance was 360 lux on the canvas, 28lux on the table and 65 lux in the eyes (white light condition, 3400 K) and the minimum illumincance was 298 lux on the canvas, 20 lux on the table and 49 lux in the eyes (orange light condition, 1600 K). Furthermore an IKEA Duderö luminaire with two 5W 170 lm saving bulbs was used to provide more light in the room.

The pulsating light changed from white (RGB values of 255 250 105) to orange (RGB values of 245 150 0) light according to the breathing curve (see Figure 20). The duration of the pauses between inhaling and exhaling are thus determined by the breathing frequency.

This resulted into the following formula, used for the R, G and B components of the light:

t = time in breathing curve

t_{top} = time when breathing curve is at maximum

t_{end} = end time of breathing curve period

C_{start} = R, G or B start value

C_{end} = R, G or B end value

$0 \leq t \leq t_{top}$: $F(t) = -((C_{end} - C_{start})/t_{top}^2) \times t^2 + 2t \times (C_{end} - C_{start})/t_{top} + C_{start}$

$t_{top} \leq t \leq t_{end}$: $F(t) = ((C_{end} - C_{start})/(t_{top} - t_{end})^2) \times t^2 + 2t \times t_{end} \times (C_{start} - C_{end})/(t_{top} - t_{end})^2$
$+ (t_{top}^2 \times C_{start} - 2 \times t_{top} \times t_{end} \times C_{start} + t_{end}^2 \times C_{end}) / (t_{top} - t_{end})^2$

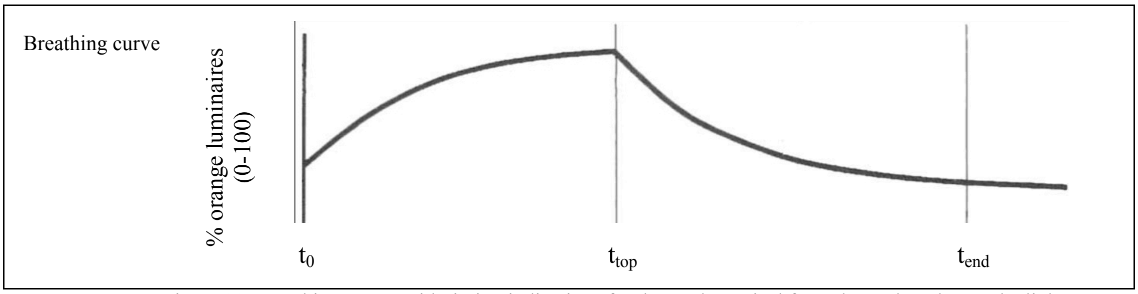


Figure 20. Breathing curve, with timing indications for the mathematical formula used to change the lights.

The pulsating light followed the breathing curve over space, by changing the color of the light from white to orange. On both on the left and the right side were 5 luminaires (see Figure 21), both showing the same behavior, but mirrored. This resulted in behavior of the luminaires, that during the inhalation more luminaires faded from white to orange from the sides towards the center, and at full inhalation all luminaires were orange. For the exhalation the luminaires faded back from orange to white, from the center towards the sides, such that at full exhalation all luminaires were white. RGB LED’s faded one by one, with a little bit of overlap between to have a smooth transition.

To provide the light stimulus with visible borders for the end of the in- and exhale, all lights were orange for the maximum inhalation, and for the maximum exhalation all lights were white, see Figure 22. The orange area would grow from the outer corners on the left and right side of the participant. With the inhalation the orange are would grow towards the middle, and then retreat again to the starting point.

The software to process the breathing data from the Nexus to decide on what frequency to start the pulsating light, was made in Labview, and communicated through an Internet socket with the Java application to control the lights.

Since the breathing rate of 6 breaths/minute is the desired frequency, all participants were guided from their own breathing rate towards a breathing frequency of 6 breaths per minute. The breathing rate changed in a linear way in steps of whole breaths per minute.

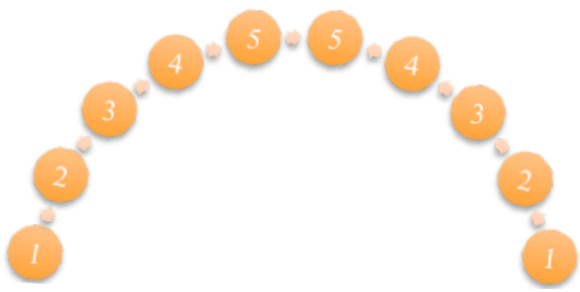


Figure 21. Distribution of the luminaires. With the inhale luminaires would fade from white to orange from luminaire 1 to 5, and with the exhale fade back to white from luminaire 5 to 1.

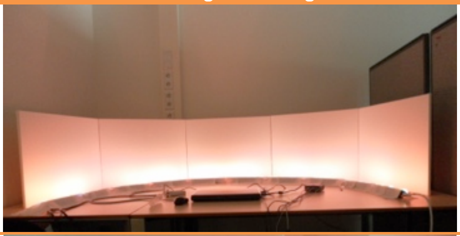
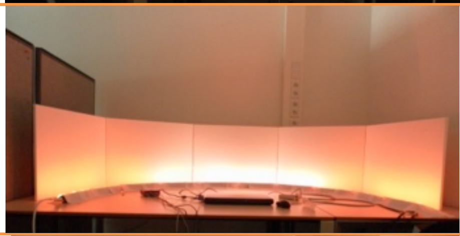
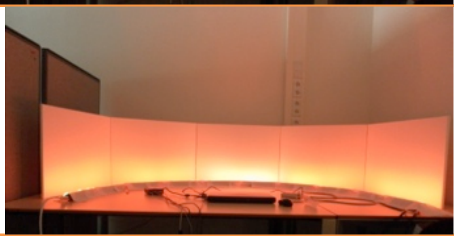
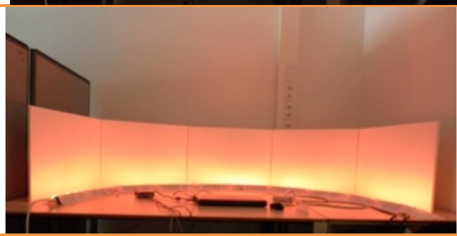
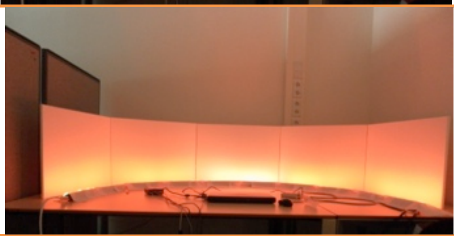
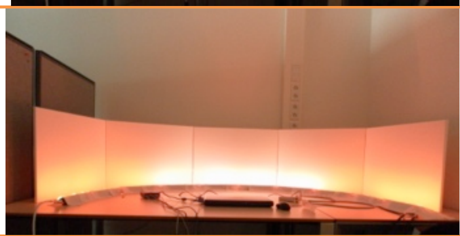
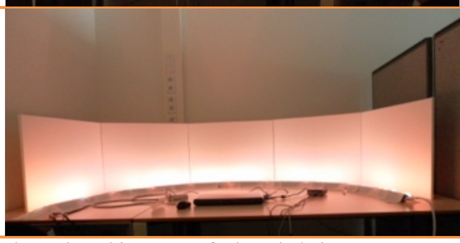
Breathing phase	Time (s)	Light Setting
Inhale	1	
Inhale	2	
Inhale	3	
Full inhalation - pause -	4	
Exhale	6	
Exhale	8	
Full exhalation - pause -	10	

Figure 22. Pulsating light, timing based on a breathing pace of 6 breaths/minute.

6.1.3 Measures

The same measures were used as in the pilot test; questionnaires and physiological measures were used, as well as the haptic interface.

6.1.3.1 Questionnaires

To measure anxiety the STAI-T and STAI-S were used. Using the same methodology as in the pilot test, we were able to construct a reliable measure for the STAI-S (α = .72) and the STAI-T (α = .82). Furthermore, the negative factor of the DES scale (α = .83) was used. As in the pilot test, the positive factor was not found to be a reliable factor (α = .24).

6.1.3.2 Physiological measures

To make sure not to lose any data, the data of the Nexus was recorded on an SD card. During the experiment the skin conductance, blood volume pulse, breathing rate and muscle activity in the arm of the participant was measured.

6.1.3.3 Breathing performance

The ability to follow the pulsating light well was defined as a deviation from the pacer frequency smaller than half a breath per minute. This was measured by the difference between the presented and the actual breathing frequency over the period that one single pace (e.g. 7 cycles/minute) was presented. The pacer decreased stepwise one breath per minute. For each frequency of the pacer, a mean deviation was derived using the following formula:

$$\frac{1}{N} \cdot \sum_{t_{n+1}}^{t_n} |Y_{measured\ breathing\ frequency\left(\frac{c}{m}\right)} - Y_{pacer\ frequency\left(\frac{c}{m}\right)}|$$

6.1.3.4 Haptic Interface

The number of squeezes in the haptic interface was used as a continuous measure of subjective anxiety during the film clips.

6.1.4 Procedure

The procedure of the experiment was the same as in the pilot test, only the third task differed, and in the final questionnaires additional questions were asked about the pulsating light (see Appendix 12.4.4). The total duration of the experiment was 45 minutes (see Table 3).

As in the pilot test the third task was a relaxation task (duration of 8 min), but in the experiment participants were asked to follow the pulsating light with their breathing during this period. A brief explanation was given to the participant that only included what light setting represented the in- and exhalation (when the light turned orange it represents the inhalation, and when it turned white the exhalation). There was no training period. The frequency of the pulsating light started at the breathing frequency of the participant, and in 8 minutes linearly decreased to 6 breaths per minute. Participants were told that they would be notified, when they could complete the last questionnaire.

Table 3. Schematic overview of the procedure during the experiment with the associated timing.

Duration	Control condition	Experimental condition
5 min	Briefing & attaching sensors	
5 min	Baseline measurement	
2 min	STAI-S & STAI-T	
8 min	Neutral film clips & Haptic Interface	Anxiety Inducing film clips & Haptic Interface
2 min	STAI-S	
8 min	Breathing with Pulsating Light	
10 min	STAI-S, DES & Final Questionnaires	
3 min	Detaching sensors	

7 Results Experiment

7.1 Manipulation Check

It was expected that watching the film clips would induce anxiety. It was expected that this would be reflected in the negative factor of the DES and in the STAI-S scores. In line with our expectations, a t-test on the negative factor of the DES suggested that participant in the experimental condition experienced more negative emotions during watching the film clips (M = 2.74, SD = .81) that participants in the control condition did (M = 1.30, SD = .34), $t(38)$ = -7.32, p < .001. This was also reflected on the STAI-S scores directly after watching the film clips, participants in the experimental condition reported more anxiety (M = 47.26, SD = 14.32) than participants in the control condition (M = 31.00, SD = 7.80), $t(39)$ = -4.84, p < .01.

7.2 Responses on the haptic interface

In line with our expectation that participants would squeeze more often when anxiety levels were higher ($H_{2.2}$), results of a non-parametric Spearman correlation test revealed significant correlations with the STAI-S administered directly after watching the film clips for the number of squeezes (r_s = .62, p < .01). STAI-S scores and the corresponding number of squeezes can be seen in Figure 23.

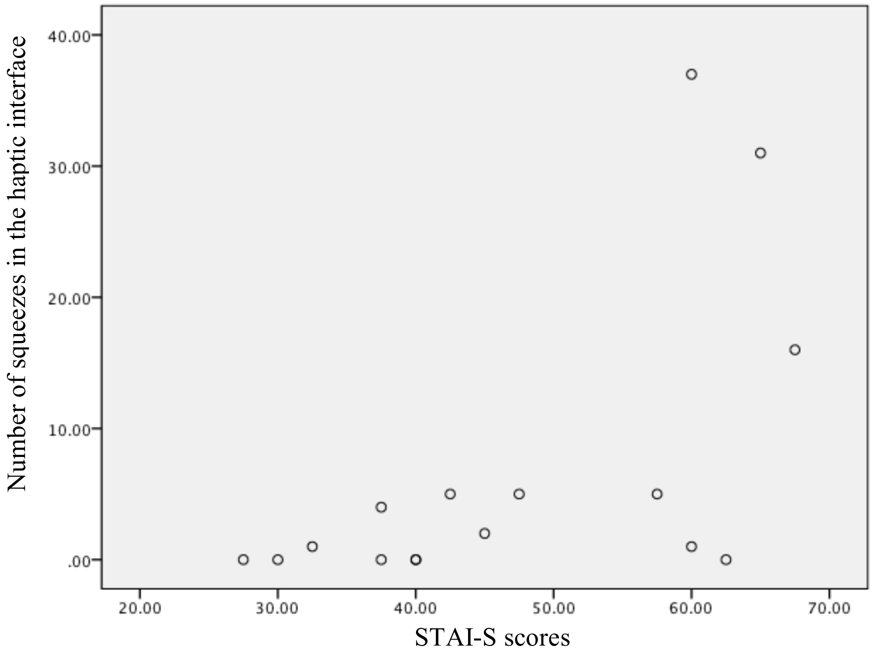


Figure 23. Scatter plot of the number of squeezes in the haptic interface and the STAI-S scores after watching the anxiety inducing film clips, for only the experimental condition.

Correlations increased, when correlating the number of squeezes in the haptic interface between the changes in STAI-S scores from baseline to after watching the film clips ($r_s = .77$, $p < .001$).

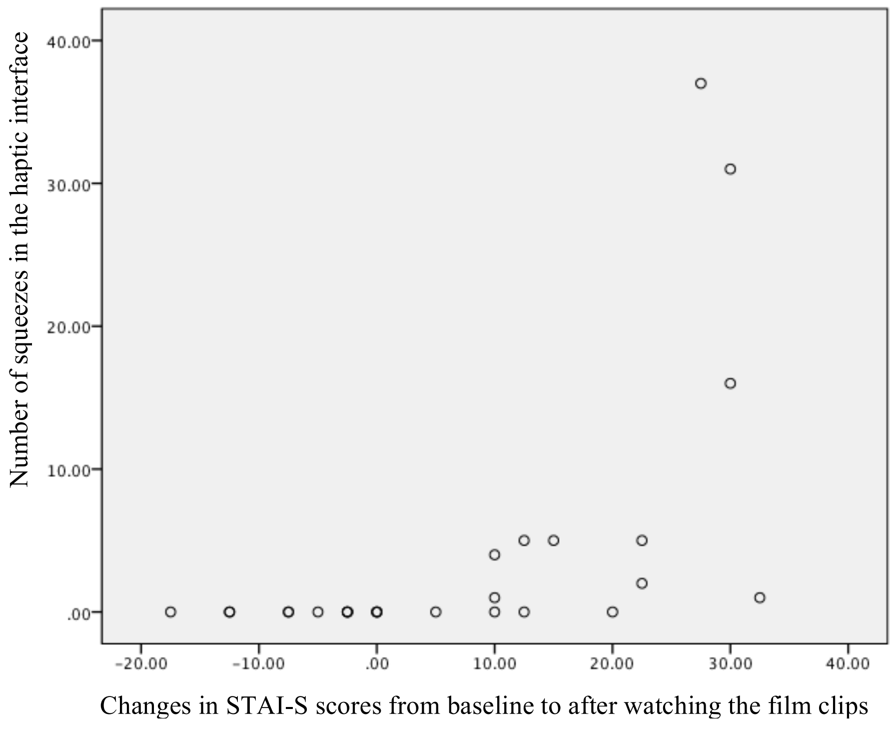


Figure 24. Number of squeezes in the haptic interface by changes in the STAI-S scores.

Furthermore, squeezes were not distributed equally over time, suggesting that for more anxious moments more squeezes were exerted to the haptic interface. This supports the assumption that the haptic interface can be used as a continuous measure for anxiety.

7.3 Ability to follow the pulsating light

In line with our hypothesis (H_3), we found that most of the people (74%) were very well able to follow the pulsating light with their breathing, on average participants were able to follow the light 83% of the time; an example of this can be seen in Figure 25. In total 63% was able to follow the pulsating light with their breathing for the whole duration of the breathing exercise.

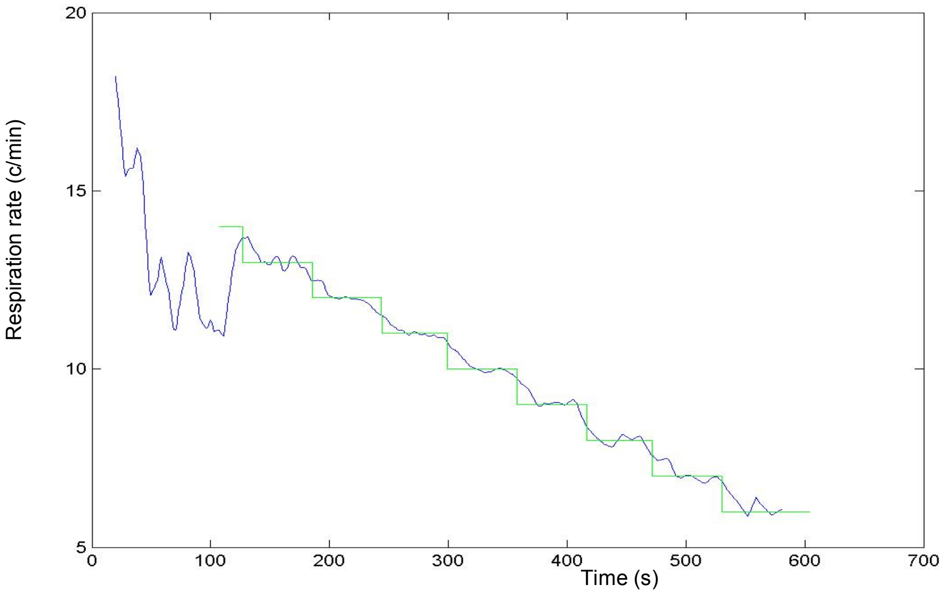


Figure 25. An example of someone following the pacer with their breathing. The green line is the pace presented by the pulsating light, the blue line is the breathing pace of the participant.

7.3.1 The effect of anxiety on the ability to follow the light

Against our expectations (H_4) that participants in the experimental condition would be less able to follow the pulsating light with their breathing than participants in the control condition, results of a t-test on the percentage of the paces participants were able to follow, thus deviating less than half a frequency from the pacer suggested that there was no difference in the ability to follow the pulsating light with one's breathing between participants in the experimental condition (M = 79.56, SD = 31.94) and in the control condition (M = 86.81, SD = 23.44), $t(24) = .66$, $p = .52$). Furthermore, a t-test was performed on the average deviation over the total 8 minutes of breathing with the pulsating light, per participant. Again, results suggested that there was no difference between the experimental condition (M = .40, SD = .31) and the control condition (M = .38, SD = .30), $t(24) = -.24$, p = .82). The hypothesis that the participants in the experimental condition would perform less well in the breathing task than participants in the control group has to be rejected.

Connected to our expectation (H_5), that higher anxiety levels would result in higher breathing rates we expected that participants in the control condition would start the breathing exercise at a higher starting pace than participants in the control condition. Especially at the end of the period in which participants were watching the film clips, there was no difference in breathing rate. Against our expectations no evidence was found for a difference in the starting frequency ($t(25) = -6.91$, $p = .496$). However, the variation in range was larger in the experimental condition, varying in a range from 6 to 18 breaths/minute ($M = 10.14$, $SD = 2.18$) than in the control condition, which varied in a range from 5 to 13 breaths/minute ($M = 10.92$, $SD = 3.57$).

The breathing data suggested that people were able to breathe regularly and were capable of adjusting their breathing pace according to the pulsating light. Data also suggested that participants did not hold on to a slow and regular breathing pace after the relaxation period as can be seen in Figure 26.

Further analysis suggested that having experience with breathing exercises did not correlate with breathing performance measured in the deviation of the breathing from the pulsation of the pulsating light ($r_s = -.220$, $p = .292$). However, the ease with which participants could follow the light slightly correlated with how good participants could relax in the period of breathing with the pulsating light, as measured by self reports ($r_s = .38$, $p = .02$). Furthermore, when the participants regarded the environment as more tense or less cozy, as measured with the negative or positive factor of the atmosphere questionnaire respectively, this was correlated with reporting more anxiety on the STAI-S during the baseline ($r_{s\_negative} = .57$, $p < .01$) ($r_{s\_positive} = -.59$, $p < .01$), and during the breathing with the light period ($r_{s\_negative} = .42$, $p < .01$) ($r_{s\_positive} = -.33$, $p < .04$), but not during watching the film clips ($r_{s\_negative} = .21$, $p = .21$) ($r_{s\_positive} = -.16$, $p = .32$). There was no difference between groups in how they perceived the environment, $t(32) = -8.26$, $p = .41$.

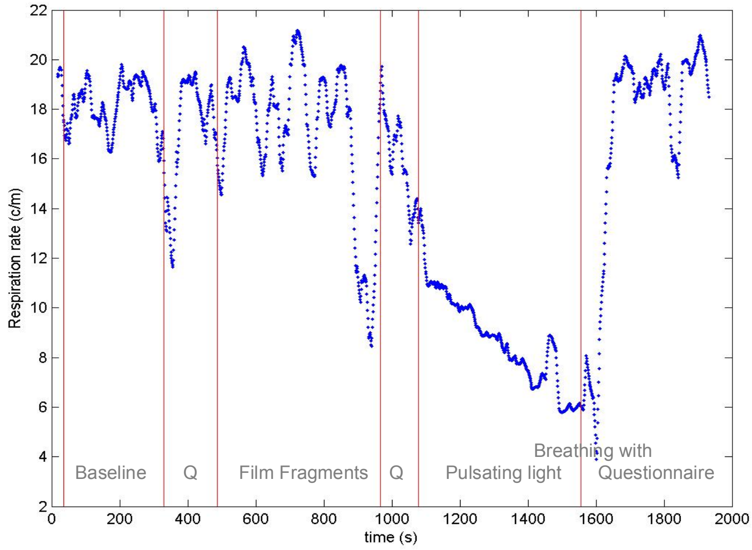


Figure 26. An example of the variability in breathing rate throughout the experiment of one participant.

7.3.2 The effect of breathing with pulsating light on subjective anxiety levels

In line with our expectations (H_6) breathing with the pulsating light reduced anxiety levels for the participants in the experimental condition as measured by the STAI-S. Results suggested that participants in the experimental condition increased anxiety levels as measured by the STAI-S after watching the anxiety inducing film clips ($M = 46.62$, $SD = 14.37$) compared to the baseline ($M = 33.38$, $SD = 10.49$), and that indeed breathing with the pulsating light in the relaxation period reduced their anxiety levels ($M = 32.88$, $SD = 9.78$), while for the control condition no changes were found in the STAI-S scores between the moments after the baseline ($M = 34.50$, $SD = 10.90$), film clips ($M = 31.00$, $SD = 7.80$) and relaxation period ($M = 31.25$, $SD = 8.83$), ($F(2, 76) = 20.653$, $p < .001$).

In line with our hypothesis (H_7) that anxiety levels would be the same after a period of 8 minutes of breathing with pulsating light for participants who started the breathing exercise with high levels of anxiety and for those starting the exercise with low levels of anxiety, results suggested that STAI-S levels were not different after the breathing exercise in the relaxation period, only at the moment after watching the film clips, there was a difference in the anxiety levels between the two conditions, ($F(2, 76) = 20.65$, $p < .01$). There was no main effect of condition, ($F(1, 38) = 3.38$, $p = .07$).

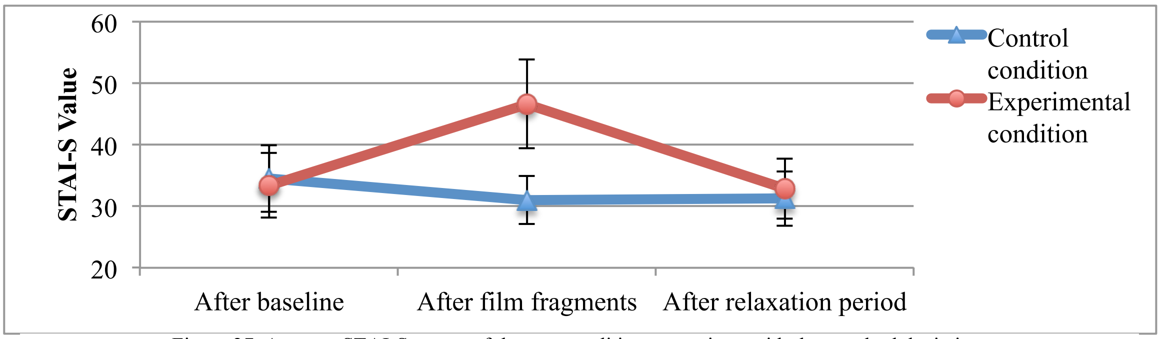


Figure 27. Average STAI-S scores of the two conditions over time, with the standard deviation.

7.3.3 The effect of watching anxiety inducing film clips and breathing with pulsating light on physiological measures

7.3.3.1 Skin Conductance

Skin conductance data was normalized on the baseline, as can be seen in Figure 28. A repeated measures ANOVA was performed with Greenhouse-Geisser correction with the average skin conductance in the 3 periods (baseline, watching film clips and breathing with the light of time) as repeated measures, and condition as between factor.

In line with our expectation that skin conductance would increase while watching the anxiety inducing film clips, and would decrease again during the relaxation period in which participants would breathe with pulsating light, results suggested that only in the experimental condition, skin conductance increased as a result of watching the film clips ($M = 81.56$, $SD = 17.38$) compared to the baseline ($M = 0.00$, $SD = 0.00$), and decreased again after the relaxation period (M = 46.49, SD = 10.55), $F(2, 70)$ = 17.07, $p < .01$. Only during watching the film clips, there was a difference between the participants in the experimental condition (M = 81.56, SD = 17.38) and in the control condition (M = 26.97, SD = 34.60), $F(2, 70)$ = 4.24, p = .04. No main effect of condition was found, $F(1, 35)$ = 3.66, p = .06.

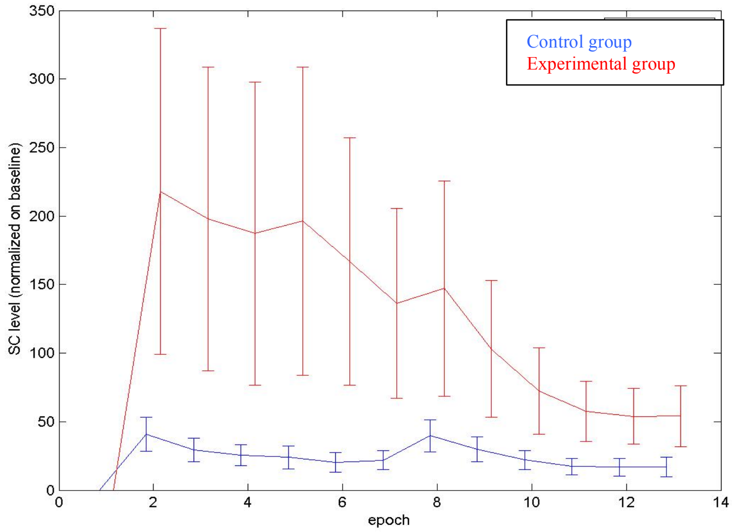


Figure 28. Skin conductance levels, normalized on the baseline, of the two groups, on different moments in time, averaged over a period of 1 minute. Epoch 1 = baseline, epoch 2-7 = film fragments, 8-13 = breathing period. Error bars represent the standard error.

Again, we also plotted the skin conductance data on a logarithmic scale, as can be seen in Figure 29. Here we can see clear trends of the different elements of the experiment. Skin conductance reduces during the baseline, and increases during completing the questionnaires. Also during breathing with the light, skin conductance reduces to a point where the two conditions do not differ significantly differ from each other anymore.

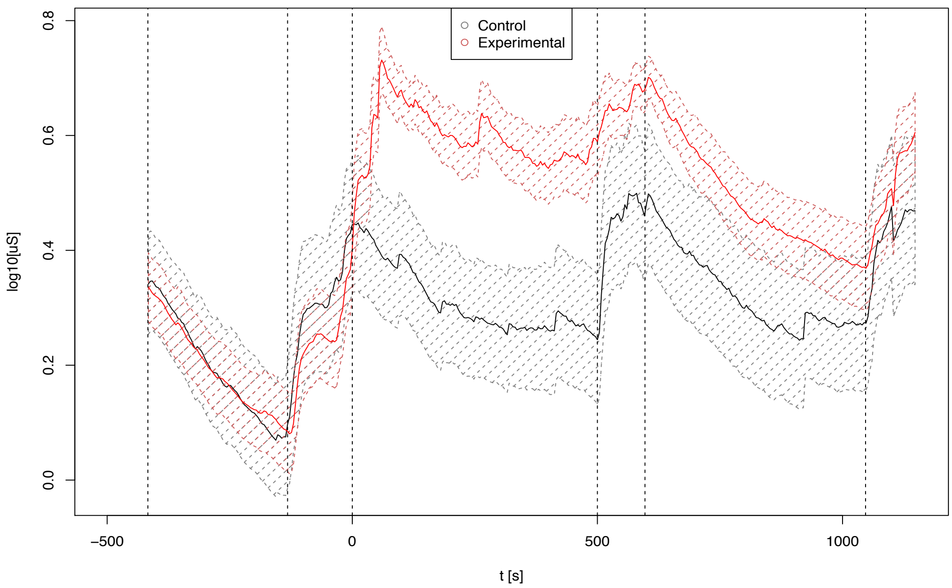


Figure 29. Skin conductance of the two conditions on a logarithmic scale, the dashed area represents the standard error. The first period represents the baseline, the second the questionnaire, the third watching the film clips, the fourth a questionnaire, the fifth a breathing period, and last the final questionnaire. In this plot, the timings are adjusted to the average, to be able to compare the participants in the same task.

7.3.3.2 Blood Volume Pulse (BVP)

In Figure 30 the average normalized InterBeat Intervals (IBI) are plotted per epoch. Results of a repeated measures ANOVA with a Greenhouse-Geisser correction suggested that there was no main effect of condition ($F(1, 36) = .089$, $p = .767$) and no difference in heart rate over time ($F(3.056, 110.026) = .662$, $p = .580$) and no interaction effect was found for condition and heart rate ($F(3.056, 110.026) = .562$, $p = .644$).

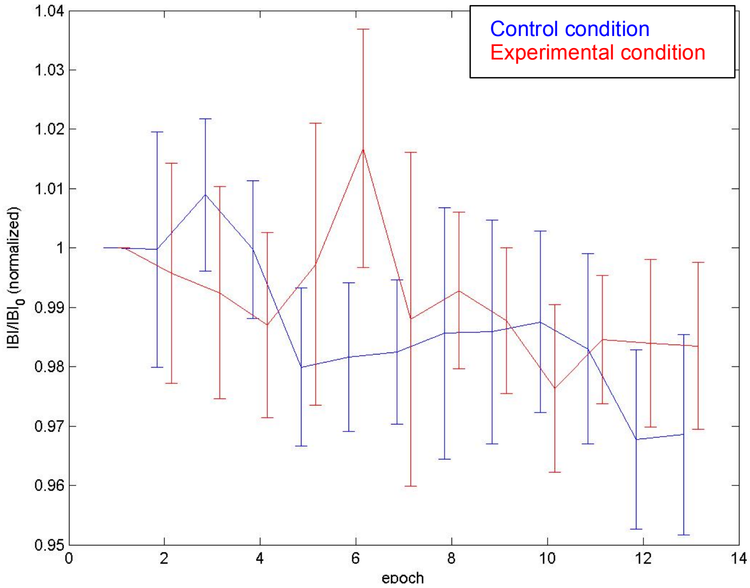


Figure 30. Heart rate in beats per minute for the two conditions over moments in time, averages were calculated over a period of 1 minute. Epoch 1 = baseline, epoch 2-7 = film fragments, 8-13 = breathing period.

7.3.3.3 Breathing

In Figure 31, the breathing data is depicted; the data was not normalized, as breathing rates were comparable between conditions. From this we can clearly see that breathing with the light decreases the breathing rate (from epoch 8 onwards). A repeated measures ANOVA with a Greenhouse-Geisser correction with the averages over the three period as repeated measure and condition as between subjects factor was done.

In line with out expectations results suggested that the breathing rate increased in the experimental group while watching the anxiety inducing film clips ($M = 16.13$, $SD = 2.94$) compared to the baseline breathing rate ($M = 14.30$, $SD = 3.26$). However, participants in the control condition also raised their breathing rate during watching the film clips ($M = 14.62$, $SD = 2.34$) as compared to baseline breathing rates ($M = 13.52$, $SD = 3.56$), $F(2, 68) = 148.20$, $p < .01$. No main effect of condition was found $F(1, 34) = 1.34$, $p = .26$. Against our expectations, there was no difference between breathing rates in the two conditions during the period in which participants were watching the film clips. Furthermore, no interaction effect of time and condition was found, $F(2, 68) = 1.05$, $p = .36$.

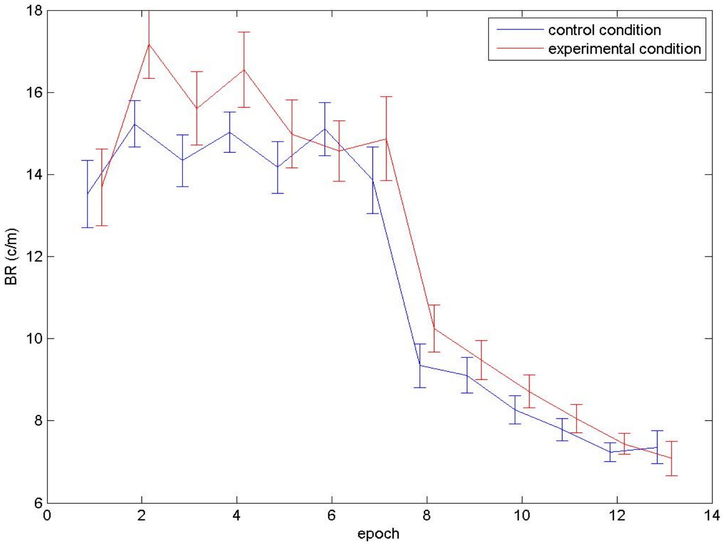


Figure 31. Breathing rates at different moments in time over a period of 1 minute; epoch 1 = baseline, epoch 2-7 = film fragments, epoch 8-13 = breathing period

8 Discussion

This study investigated whether lowering the breathing pace by following pulsating light as a breathing guide could help to reduce anxiety.

First of all, we expected that people could follow the light with their breathing. Results suggested that pulsating light as presented in this study was a breathing guide, which was easy to follow for people. Participants were able to follow the guide for more than 80% of the time until 6 breaths per minute. This hypothesis is therefore accepted. Earlier research of Brandt (2010) investigating the use of pulsating light as a breathing guide, did not find such good results for the ability of people to follow the pulsating light. Compared to the stimulus Brandt had presented, the stimulus used in this study had visible boarders that probably made it easier for the participant to anticipate on the start of inhaling or exhaling. Furthermore, the pulsation of the light followed the breathing curve, making it a natural representation of the breathing. Furthermore, the participants were surrounded by the luminaires. Participants commented: “it felt like the light was moving with me” and “it feels very natural to breathe along with the light”. However, because we matched the pulsation of the light to the standard breathing curve, this was not ideal for all participants. The main reasons that were given were that the dynamics of the light were not suitable for their normal breathing pattern. Some people indicated to prefer longer or shorter pauses between the maximum inhale or exhale. Some people even regarded the pace of 6 breaths per minute as too fast, which was quite remarkable, since most participants had a breathing tempo much higher than 6 breaths per minute during the other elements of the experiment. Another important observation was how fast people could lower their breathing initially. This suggests that it might be better for the pacer to drop the frequency faster in the beginning, because people otherwise experience this as a breathing tempo that is much too fast. However, more research is needed to confirm this.

Another reason to adapt the dynamics of the pulsating light to the breathing pattern of the participant is that when someone is experiencing hyperventilation, and is breathing superficially with full lungs, it is more effective to emphasize a longer exhale, rather than making the timing for the whole breathing curve longer. One technique to increase the time spend on exhaling, is exhaling with sound through the mouth. To help someone to reduce high breathing paces, it could help to give instructions on how to achieve this. Future research could study the effect of added instructions or sound to the visual representation. It could well be possible that through multi-sensory stimulation, the power of the cues could reinforce each other. More research is needed to see how this affects the relaxation response. Furthermore, studying if it is easier to follow the pulsating light when it pulsates according to someone's personal breathing curve could enhance the anxiety reducing experience is valuable. Our results suggested that when breathing with the light is experienced as easy, more anxiety was reduced. In this study participants indicated that the different breathing dynamics from the pulsating light was the main reason that made it hard to follow.

The fact that participants could follow the pulsating light well without a training period, is very promising. It could well be possible that the cues given in this study, and the way people were guided from their own breathing pace to 6 breaths/minute was easier to follow for the participants, than other cues given in previous studies (Brandt, 2010; Gavish, 2010).

We expected that lowering the breathing pace by following the pulsating light with one's breathing would elicit a relaxation response. This hypothesis is accepted, as the experimental group showed a significant decrease in anxiety levels. This finding is in line with earlier research (Peng et al., 2004). Although the results can not be compared one on one with the results from the pilot test, the trend from the pilot test showed that after a relaxation period without pulsating light, the effect of the anxiety inducement sustained as measured by the STAI-S. In contrast, in the experiment participants in both conditions reported the same values of anxiety after breathing with the pulsating light. Additional research is needed to see compare the two relaxation methods. Furthermore, results of Wan (2011) suggested that orange pulsating light was one of the most promising light settings for stress recovery. A condition with pulsating light without the instruction to breathe along could be added, to investigate the relaxing effect of the pulsating light on itself.

Another hypothesis was that it would be harder for anxious people to lower their breathing pace by following the pulsating light with one's breathing. Results did not provide evidence for this since both groups had a similar breathing performance. Therefore, this hypothesis has to be rejected. However, at the moment when participants were watching the final minutes of the film clips, breathing rates were the same in the two conditions. The hypothesis that anxious people would start at a higher breathing rate is therefore also rejected.

There was also no difference in the starting pace of the breathing exercise. This could also explain why there was no difference found between conditions. It could be possible that for larger differences in anxiety, when the person experiences multiple symptoms of anxiety, a difference can be found. The anxiety induced in this experiment is not the same as the anxiety someone experiences when undergoing an MRI scan, as there is no personal threat of for instance the outcome of the procedure. However, during the experiment, unfortunately one participant quitted because she could not stand watching the film fragment anymore, and she was very upset. Her breathing rate increased from 5 breaths per minute during the baseline to 25 breaths per minute during the film clips. After she decided to stop the experiment and drank some water she choose to try the relaxation period of breathing with the pulsating light to be try to calm down. She was able to follow the presented light very well, and also indicated that it worked for her to calm down. Although this is just one case, this is very promising for the application of pulsating light as an anxiety-reducing medium.

Furthermore, we expected that participants would squeeze more in the haptic interface if they felt more anxious. Results suggested that indeed participants squeezed more when their anxiety level was higher as measured by the STAI-S. More tests are needed to see what kind of relation can be found between anxiety levels and the number of squeezes. There were some participants that did not squeeze a lot, but had large increases in STAI-S scores after watching the film clips. It could be possible that not everybody will express his or her anxiety similarly. For instance more introvert people might have another threshold before indicating their anxiety by squeezing. It could also be possible that the presence of the experiment leader had lead to less communication of their anxiety through the haptic interface. More research is needed to answer these questions.

The results of this study suggest that pulsating light can be used as a breathing guide, to lower people's breathing rate. It also suggested that breathing with the pulsating light could help to recover from anxiety, and that the state of anxiety one is in, does not influence how well this person can follow the pulsating light. The fact that subjective anxiety levels decreased substantially, supports the idea that pulsating light can be used to improve the patient experience.

A limitation of this study was that this was a lab study, in which anxiety was induced with film clips. In an MRI scanning procedure, patients feel personal threat and have real worries about the outcomes of scan, while in this study the experienced anxiety might be based more on empathy with the characters in the movie. Before testing the pulsating light as a breathing guide is tested with anxious MRI patients, we advise to investigate long-term effects are of using pulsating light to learn paced breathing. It could be that training with this light under normal circumstances helps to cope with anxiety in a stressful situation. The stimulus could function as a familiar element in an unfamiliar MRI room, which could increase the feeling of safety. According to the fight-flight theory, feeling safe is one of the premises of being able to relax. Furthermore, practicing paced breathing at home could help the patient to recognize the breathing guide as a coping mechanism for anxiety.

Previous studies have found a strong learning effect in paced breathing. However, no study has been done yet into presenting a breathing guide as a coping mechanism for anxiety. Although a study has been done, with good results, on training paced breathing as a coping technique (Meuret et al., 2001), the effect of having a familiar breathing cue in an unfamiliar situation has not been tested yet.

9 Conclusion

Supporting our expectation that higher levels of anxiety would result into more squeezes in the haptic interface, results suggested that participants squeezed more as their anxiety levels increased. Furthermore, the squeezes were not divided equally over time, suggesting that for more anxious moments more squeezes were exerted to the haptic interface.

In line with our expectation that people could follow the pulsating light with their breathing, for more than 80% of the time people could follow the pulsating light. More than 63% could follow the pulsating light 100% of the time. Against our expectations that anxiety would make it harder for participants to follow the light, no difference was found in the ability to follow the presented light between anxious and non-anxious people. Furthermore, results suggested that there was no difference in starting pace between conditions. However, at the end of watching the film clips, there was no difference anymore in breathing rate between conditions.

In line with our hypothesis that breathing with the pulsating light in a slow pace would reduce anxiety, results suggested that lowering breathing rate using pulsating light as a guide indeed reduced subjective anxiety levels.

Based on the breathing performance and the additional comments can be concluded that pulsating light as presented in this study was generally regarded as a clear and intuitive way to be guided to inhale and exhale. However, when the breathing pattern of the participant was very different from the presented breathing pattern, it was experienced as somewhat hard to follow the light. This did not influence the participant's breathing performance, but difficulties with following the light were correlated with higher anxiety levels. From this can be concluded that pulsating light is a very promising medium to reduce anxiety levels, and that there is some room for improvement to make it easier for people to follow.

10 Acknowledgements

First of all, I want to thank everybody who was willing to participate in my experiments. A special thanks goes out to to Roel Cuppen, who realized the pulsating light. Furthermore, I want to thank Jaap Ham, Yvonne de Kort, Laura Klaming, Hans Weda and Ad Denissen for their guidance throughout the project. A final thanks goes to Juergen Vogt and Richard van der Wolf, for their assistance on the technical aspects of the study.

11 References

Badger, J. M. (1994). Calming the Anxious Patient. *The American Journal of Nursing*, *94*(5), 46–50.

Benchetrit, G. (2000). Breathing pattern in humans: diversity and individuality. *Respiration physiology*, *122*(2-3), 123–9.

Benson, H. (1993). The Relaxation Response. In D. Goleman & J. Gurin (Eds.), *Mind Body Medicine How to use Your Mind for Better Health* (pp. 125–149). New York: Consumers Reports Book.

Bernardi, L., Porta, C., Gabutti, A., Spicuzza, L., & Sleight, P. (2001). Modulatory effects of respiration. *Autonomic neuroscience*, *90*(1-2), 47–56.

Bernstein, D. A., & Borkovec, T. D. (1973). *Progressive relaxation training: A manual for the helping profession*. Champaign, IL: Research Press.

Biofeedback, A. for A. P. and. (2011). About Biofeedback. Retrieved August 1, 2012, from http://www.aapb.org/i4a/pages/index.cfm?pageid=3463

Bludszuweit, M. (2009). Light and Color: Healthcare Lighting presented by Siemens. Erlangen: Siemens AG. Retrieved from http://www.siemens.com/press/pool/de/pressemitteilungen/2009/workflow_solutions/HWS2009 11013e.pdf

Brandt, I. (2010). *The influence of rhythmic changes in lighting on breathing rhythm and relaxation*. Eindhoven University of Technology.

Clark, D. M., Salkovskis, P. M., & Cbalkley, A. J. (1985). Respiratory control as a treatment for panic attacks. *Journal of Behavior Therapy and Experimental Psychiatry*, *16*, 23–30.

Clark, M. E., & Hirschman, R. (1990). Effects of paced respiration on anxiety reduction in a clinical population. *Biofeedback and self-regulation*, *15*(3), 273–84.

Douglas, C. G., & Haldane, J. S. (1905). The Regulation of Normal Breathing. *Physiological Laboratory*, *23*, 420–440.

Edwards, A. D., & Arthurs, O. J. (2011). Paediatric MRI under sedation: is it necessary? What is the evidence for the alternatives? *Pediatric radiology*, *41*(11), 1353–64.

Eisen, A. R., Rapee, R. M., & Barlow, D. H. (1990). The Effects of Breathing Rate and pC02 , Levels on Relaxation and Anxiety in a Non-Clinical Population. *Journal of Anxiety Disorders*, *4*, 183–190.

Ford, M. R., Stroebel, C. F., Strong, P., & Szarek, B. L. (1983). Quieting Response training: Predictors of long-term outcome. *Biofeedback and Self-Regulation*, *8*, 393–408.

Gavish, B. (2010). Device-guided breathing in the home setting: technology, performance and clinical outcomes. *Biological psychology*, *84*(1), 150–6.

Gilbert, C. (2003). Clinical Applications of Breathing Regulation: Beyond Anxiety Management. *Behavior Modification*, *27*(5), 692–709.

Gillani, N. B., & Smith, J. C. (2001). Zen meditation and ABC relaxation theory: an exploration of relaxation states, beliefs, dispositions, and motivations. *Journal of clinical psychology*, *57*(6), 839–46.

Grey, S. J., Price, G., & Mathews, a. (2000). Reduction of anxiety during MR imaging: a controlled trial. *Magnetic resonance imaging*, *18*(3), 351–5.

Hewig, J., Hagemann, D., Seifert, J., Gollwitzer, M., Naumann, E., & Bartussek, D. (2005). A revised film set for the induction of basic emotions. *Cognition and Emotion*, *19*(7), 1095–1109.

Horst, M. (2012). *Testing a Haptic Interface as a Continuous Measure for Anxiety*. Philips Research Eindhoven.

Iwata, N., & Higuchi, H. R. (2000). Journal of Personality Responses of Japanese and American University Students to the STAI Items That Assess the Presence or Absence of Anxiety. *Journal of Personality Assessment*, *74*(July 2012), 48–62.

Izso, L., Lang, E., Laufer, L., Suplicz, S., & Horvath, a. (2009). Psychophysiological, performance and subjective correlates of different lighting conditions. *Lighting Research and Technology*, *41*(4), 349–360.

Katz, R. C., Wilson, L., & Frazer, N. (1994). Anxiety and its Determinants in Patients undergoing MRI. *Journal of Behavior Therapy & Experimental Psychiatry*, *25*(2), 131–134.

Kenner, C. C. (2009). *Comparison of Two Relaxation Techniques to Reduce Physiological Indices of Anxiety in an Person with Mild Mental Retardation. Image (Rochester, N.Y.)*. East Carolina University.

Laufer, L., Lang, E., Izso, L., & Nemeth, E. (2009). Psychophysiological effects of coloured lighting on older adults. *Lighting Research and Technology*, *41*(4), 371–378.

Lehrer, P. M., Vaschillo, E., & Vaschillo, B. (2000). Resonant frequency biofeedback training to increase cardiac variability: rationale and manual for training. *Applied psychophysiology and biofeedback*, *25*(3), 177–91.

Ley, R. (1999). The Modification of Breathing Behavior: Pavlovian and Operant Control in Emotion and Cognition. *Behavior Modification*, *23*(3), 441–479.

Lukins, R., Davan, I. G. P., & Drummond, P. D. (1997). A Cognitive Behavioural Approach to Preventing Anxiety During MRI. *Journal of Behavioral Therapy and Experimental Psychiatry*, *28*(2), 97–104.

Magnetic Resonance Safety Policy of UCSF. (2012). Retrieved July 20, 2012, from www.radiology.ucsf.edu/patient-care/patient-safety/mri/policy

McIsaac, H. K., Thordarson, D. S., Shafran, R., Rachman, S., & Poole, G. (1998). Claustrophobia and the magnetic resonance imaging procedure. *Journal of Behavioral Medicine*, *21*(3), 255–268.

Meuret, A. E., Wilhelm, F. H., Ritz, T., & Roth, W. T. (2003). Breathing Training for Treating Panic Disorder: Useful Intervention or Impediment? *Behavior Modification*, *27*(5), 731–754.

Meuret, A. E., Wilhelm, F. H., & Roth, W. T. (2001). Respiratory Biofeedback-Assisted Therapy in Panic Disorder. *Behavior Modification*, *25*(4), 584–605.

Mook, J., van der Ploeg, H. M., & Kleijn, W. C. (2007). Symptom-positive and symptom-negative items in the state-trait anxiety inventory: A comparison and replication. *Anxiety, Stress & coping: An International Journal*, *5*(2), 113–123.

Murphy, K. J., & Brunberg, J. A. (1997). Adult Claustrophobia, Anxiety and Sedation in MRI. *Magnetic Resonance Imaging*, *15*(1), 51–54.

Ndao, D. H., Ladas, E. J., Cheng, B., Sands, S. A., Snyder, K. T. (2010). Inhalation aromatherapy in children and adolescents undergoing stem cell infusion : results of a placebo- controlled double-blind trial. *Psycho-Oncology*.

Parati, G., Malfatto, G., Boarin, S., Branzi, G., Caldara, G., Giglio, A., Bilo, G., et al. (2008). Device-Guided Paced Breathing in the Home Setting Effects on Exercise Capacity , Pulmonary and Ventricular Function in Patients With Chronic Heart Failure : A Pilot Study. *System*, 178–183.

Peng, C.-K., Henry, I. C., Mietus, J. E., Hausdorff, J. M., Khalsa, G., Benson, H., & Goldberger, A. L. (2004). Heart rate dynamics during three forms of meditation. *International journal of cardiology*, *95*(1), 19–27.

Philips, S., & Deary, I. J. (1995). Interventions to Alleviate Patient Anxiety During Magnetic Resonance Imaging: A Review. *Radiography*, *1*, 29–34.

Pirhonen, A., & Tuuri, K. (2011). Calm Down – Exploiting Sensorimotor Entrainment in Breathing Regulation. In E. W. Cooper, V. V. Kryssanov, H. Ogawa, & S. Brewster (Eds.), *Haptic and Audio Interaction Design 2011, Kyoto, Japan. Lecture Notes in Computer Science (LNCS 6851)* (pp. 61–70). Berlin Heidelberg: Springer-Verlag.

Postolache, O., Girão, P. S., Pinheiro, E., & Postolache, G. (2010). Unobtrusive and Non-invasive Sensing Solutions for On-Line Physiological Parameters Monitoring. In A. Lay-Ekuakille & S. C. Mukhopadhyay (Eds.), *Wearable and Autonomous Biomedical Devices and Systems for Smart Environment* (pp. 277–314). Berlin Heidelberg: Springer-Verlag.

Rakel, D., & Faass, N. (2006). *Complementary medicine in clinical practice: integrative practice in American healthcare*. Sudbury: Jones & Bartlett Learning.

Rambaudi, L. R., Rossi, E., Mántaras, M. C., Perrone, M. S., & Siri, L. N. (2007). Visual aided pacing in respiratory maneuvers. *Journal of Physics: Conference Series*, *90*, 012034.

Rassler, B., & Raabe, J. (2003). Co-ordination of breathing with rhythmic head and eye movements and with passive turnings of the body. *European journal of applied physiology*, *90*(1-2), 125–30.

Redd, W. H., Manne, S. L., Peters, B., Jacobsen, P. B., & Schmidt, H. (1994). Fragrance administration to reduce anxiety during MR imaging. *Journal of magnetic resonance imaging : JMRI*, *4*(4), 623–6.

Redelmeier, D. A., & Kahneman, D. (1996). Patients' Memory of Painful Medical Treatments: Real-time and retrospective evaluations of two minimally invasive procedures. *Pain*, *66*, 3–8.

Relaxation. (n.d.). New Oxford American Dictionary.

Ruef, A. M., & Levenson, R. W. (2007). Continuous Measurement of Emotion: The affect Rating Dial. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 286–297). New York: Oxford University Press.

Sainsbury, P., & Gibson, J. G. (1954). Symptoms of Anxiety and Tension and the Accompanying Physiological Changes in the Muscular System. *Journal of Neurosurgical Psychiatry*, *17*, 216–224.

Schaefer, A., Nils, F., Sanchez, X., & Philippot, P. (2010). Assessing the effectiveness of a large database of emotion-eliciting films: a new tool for emotion researchers. *Cognition and Emotion*, *24*(7), 1153–1172.

Schein, M. H., Gavish, B., Herz, M., Naveh, P., & Knishkowy, B. (2001). Treating hypertension with a device that slows and regularises breathing : a randomised , double-blind controlled study. *Journal of Human Hypertension*, *15*, 271–278.

Sherwood, L. (2010). The Respiratory System. *Human Physiology: From Cells to Systems* (7th ed., pp. 461–491). Belmont: Cengage Learning. Retrieved from http://books.google.nl/books?id=jl4rLDuewo4C&pg=PT377&lpg=PT377&dq=The+Respiratory+System+sherwood&source=bl&ots=zSuBbu3LWv&sig=8eAYOTcd-_kAJxTmh2j4Id7DeFk&hl=nl&sa=X&ei=9EeyT5TeGJCZ8gPUmIzLCQ&ved=0CFwQ6AEwAQ#v=onepage&q&f=false

Smith, N., & Tausk, F. A. (2010). Stress, Relaxation, and General Well-Being. In R. Norman (Ed.), *Preventive Dermatology* (pp. 3–16). London: Springer London. doi:10.1007/978-1-84996-021-2

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stress-Sensing Watches. (n.d.). Retrieved August 13, 2012, from http://www.trendhunter.com/trends/biofeedback-stresswatch

Thomason, M. E., & Glover, G. H. (2008). Controlled inspiration depth reduces variance in breath-holding-induced BOLD signal. *NeuroImage*, *39*(1), 206–14.

Tischler, V., Calton, T., Williams, M., & Cheetham, A. (2008). Patient anxiety in magnetic resonance imaging centres: Is further intervention needed? *Radiography*, *14*(3), 265–266.

van Knippenberg, F. C. E., Duivenvoorden, H. J., Bonke, B., & Passchier, J. (1990). Shortening the State-Trait Anxiety Inventory. *Journal of Clinical Epidemiology*, *43*(9), 995–1000.

Vaschillo, E. G., Vaschillo, B., & Lehrer, P. M. (2006). Characteristics of resonance in heart rate variability stimulated by biofeedback. *Applied psychophysiology and biofeedback*, *31*(2), 129–42.

Vaughan, B. (2009). A more scenic scan. *Password*, (34), 4–9.

Vogel, W. V., Valdés Olmos, R. A., Tijs, T. J. W., Gillies, M. F., Van Elswijk, G., & Vogt, J. (2012). Intervention to lower anxiety of 18 F-FDG PET / CT patients by use of audio-visual imagery during the uptake phase prior to imaging. *Journal of Nuclear Medical Technology*, *40*(2), 92–98.

Vogels, I. (2008). Atmosphere Metrics: Development of a Tool to Quantify Experienced Atmosphere. In J. H. D. M. Westerink, M. Ouwerkerk, T. J. M. Overbeek, W. F. Pasveer, & B. Ruyter (Eds.), *Probing Experience* (pp. 25–41). Springer Netherlands.

Wan, S. H. (2011). *An explorative study about the effect of pulsating lighting on stress- recovery*. Eindhoven University of Technology.

Wells, J. V., Howard, G. S., Nowlin, W. F., & Vargas, H. J. (1986). Presurgical anxiety and postsurgical pain and adjustment: Effects of a stress inoculation procedure. *Journal of Consulting and Clinical Psychology*, *54*, 831–835.

Zapka, J. G., Palmer, R. H., Hagraves, J. L., Nerenz, D., Frazier, H. S., & Warner, C. K. (1995). Relationships of Patient Satisfaction with Experience of System Performance and Health Status. *The Journal of Ambulatory Care Management*, *18*(1), 73–83.

Zeidner, M., & Matthews, G. (2011). *Anxiety 101*. (Ja. C. Kaufman, Ed.) (pp. 1–40). New York: Springer Publishing Company.

Zeier, H. (1984). Arousal Reduction with Biofeedback-Supported Respiratory Meditation 1. *Biofeedback and self-regulation*, *9*(4), 497–508.

12 Appendix A: Questionnaire

12.1 STAI-T

Hieronder vind je een aantal uitspraken die door mensen zijn gebruikt om zichzelf te beschrijven. Lees iedere uitsprak door een selecteer een vakje bij die uitspraak om daarmee aan te geven hoe je je in het algemeen voelt. Er zijn geen goede of slechte antwoorden. Denk niet te lang na en geef je eerste indruk. Het gaat er dus om dat je bij deze vragenlijst weergeeft hoe je je in het algemeen voelt.

Hoe voel je je in het algemeen?

	Bijna nooit	Soms	Vaak	Bijna altijd
1. Ik voel me prettig	1	2	3	4
2. Ik voel me nerveus en onrustig	1	2	3	4
3. Ik voel me uitgerust	1	2	3	4
4. Ik voel me rustig en beheerst	1	2	3	4
5. Ik word geplaagd door storende gedachten	1	2	3	4
6. Ik heb gebrek aan zelfvertrouwen	1	2	3	4
7. Ik voel me op mijn gemak	1	2	3	4
8. Ik ben gelijkmatig van stemming	1	2	3	4

12.2 STAI-S

Hieronder vind je een aantal uitspraken die door mensen zijn gebruikt om zichzelf te beschrijven. Lees iedere uitsprak door een selecteer een vakje bij die uitspraak om daarmee aan te geven hoe je je op dit moment voelt. Er zijn geen goede of slechte antwoorden. Denk niet te lang na en geef je eerste indruk. Het gaat er dus om dat je bij deze vragenlijst weergeeft hoe je je op dit moment voelt.

Hoe voel je je in het algemeen?

	Geheel niet	Een beetje	Tamelijk veel	Zeer veel
1. Ik voel me onrustig	1	2	3	4
2. Ik voel me op mijn gemak	1	2	3	4
3. Ik pieker over nare dingen die kunnen gebeuren	1	2	3	4
4. Ik voel me aangenaam	1	2	3	4
5. Ik voel me nerveus	1	2	3	4
6. Ik ben ontspannen	1	2	3	4
7. Ik voel me tevreden	1	2	3	4
8. Ik voel me evenwichtig	1	2	3	4

12.3 Demographics

1. Wat is je leeftijd (in jaren)?
2. Welke studie volg je op dit moment of heb je gevolgd?

12.4 Film clips

1. Kun je aan geven welke films je al eerder hebt gezien (voor vandaag)?
2. Geef aan hoe graag je normaal gesproken de volgende genres kijkt:

	Heel graag	Redelijk graag	Neutraal	Niet zo graag	Helemaal niet graag
Thrillers					
Horror					

3. Wat vond je van de filmfragmenten?

	Helemaal van toepassing	Enigzins van toepassing	Neutraal	Enigzins niet van toepassing	Geheel niet van toepassing
1. Eng					
2. Saai					
3. Spannend					
4. Grappig					
5. Schokkend					
6. Leuk					

4. Was er een spannend moment in de film?
   - o Nee
   - o Ja, namelijk: .....

12.4.1 Self reported emotional arousal

5. Hoe sterk was de emotie die de film bij je teweeg bracht? Geef dit aan op een schaal van 1 tot 10, waarbij 1 staat voor “geen emotie”en 10 voor “de sterkste emotie die ik ooit gevoeld heb”.

1 2 3 4 5 6 7 8 9 10

12.4.2 DES

6. In hoeverre heb je de volgende emoties ervaren tijdens het kijken van de filfragmenten?

	Helemaal niet	Niet echt	Neutraal	Enigzins	Heel sterk
1. geconcentreerd					
2. geamuseerd					
3.verdrietig					
4. geïrriteerd					
5. angstig					
6. gespannen					
7. walging					

8. minachting					
9. verrast					
10. verheugd					

12.4.3 Relaxation

7. Hoe goed kon je ontspannen

	Heel goed	Redelijk goed	Neutraal	Redelijk slecht	Heel slecht
Tijdens de film?					
Na de film?					

8. Heb je ervaring met ademhalingsoefeningen? (bv. Yoga)
    - o Nee
    - o Ja, ik heb ervaring met: ....

12.4.4 Light

9. Hoe moeilijk of makkelijk was het om het licht te volgen met je ademhaling?

Heel moeilijk	Redelijk moeilijk	Neutraal	Redelijk makkelijk	Heel makkelijk

10. Wat maakte dit moeilijk of makkelijk?

11. Geef aan in welke mate de volgende aspecten van toepassing zijn op het licht?

	Helemaal niet van toepassing	Enigzins niet van toepassing	Neutraal	Enigzins van toepassing	Helemaal van toepassing
Voorspelbaar					
Ontspannend					
Onrustig					
Te fel (intensiteit van het licht)					
Te fel (intensiteit van de kleur)					

12. Werd je ergens door afgeleid tijdens het meeademen met het licht?
    - o Nee
    - o Ja, door: ......

12.4.5 Atmosphere

13. Geef aan in hoeverre de volgende beschrijvingen van toepassing zijn op deze ruimte:

	Helemaal niet	Enigzins niet	Neutraal	Enigzins	Helemaal
1. Afstandelijk					
2. Levendig					
3. Beangstigend					
4. Luxueus					
5. Bedompt					
6. Mysterieus					
7. Bedreigend					
8. Ongedwongen					
9. Behaaglijk					
10. Ongemakkelijk					
11. Beklemmend					
12. Onrustig					
13. Deprimerend					
14. Ontspannen					
15. Enerverend					
16. Persoonlijk					
17. Formeel					
18. Romantisch					
19. Gastvrij					
20. Ruimtelijk					
21. Geborgen					
22. Rustgevend					
23. Gemoedelijk					
24. Saai					
25. Gespannen					
26. Sloom					
27. Gezellig					
28. Stimulerend					
29. Inspirerend					
30. Toegankelijk					
31. Intiem					
32. Vijandig					
33. Kil					

34. Vrolijk					
35. Knus					
36. Warm					
37. Koud					
38. Zakelijk					