MASTER

The influence of rhythmic changes in lighting on breathing rhythm and relaxation

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The influence of rhythmic changes in lighting on breathing rhythm and relaxation

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Relax and enjoy!

Preface

At this moment you are reading the preface of the final research report of my Master education at TU Eindhoven. After my Bachelor education Industrial Design Engineering at Twente University, I moved to Eindhoven and I still do not regret this choice. The last three years I studied Human-Technology Interaction with great enthusiasm and interest in the topics provided by the professors. This thesis is the result of six years of extensive learning and I hope you will enjoy reading it.

There are several people without whom this thesis would not have been possible. I want to thank Jaap Ham and Daniel Lakens, my supervisors from the TU Eindhoven, for their supervision and useful insights during this project. I also would like to thank Philips Research for providing me the opportunity to graduate inside their company. Specifically Hans Weda helped me a lot through all stages of the process and Roel Cuppen was always enthusiastic and optimistic about the outcomes of the project, whatever they would be. Thanks to you both. The people who talked to me about rhythms, relaxation and lighting were very helpful as well, thank you for your time. And of course I have to thank my great sparring partner, Mieke Kleppe. Without her this thesis would not be so full of beautiful ANOVA's. Last but definitely not least I want to thank my parents for supporting me in everything I do.

Chapter 1 describes the state of the current research and introduces the present studies. Chapter 0 describes an experiment which shows that people are capable of synchronizing their breathing with an external lighting stimulus and in chapter 3 an experiment about unconscious synchronization with a lighting rhythm is described. In chapter 4, a general discussion will discuss the implications of both experiments and some possibilities for future research.

Abstract

Earlier research has shown that paced breathing is shown to be effective to relax people. Also, research indicates that people are able to synchronize their respiration with auditory and bodily rhythms. The current two experiments were executed to find out if people are also able to synchronize their breathing rhythm with a visual rhythm and relax in this setting. In experiment 1, participants were instructed to breathe in synchrony with lighting that gradually changed in illuminance to guide them to relaxation. Results suggest that some people were able to follow this lighting rhythm with their breathing pattern. Experiment 2 used the same lighting conditions, but the participants were not instructed to synchronize their breathing with the rhythmic lighting. Results show that people did not synchronize with rhythmic changes in lighting and even became more stressed by the rhythmic lighting. From these studies we can conclude that people are able to consciously slow down their breathing rate according to lighting rhythms, but they do not synchronize breathing with a lighting rhythm when they are not instructed to.

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1 Introduction

People have to and like to relax every once in a while. Relaxing can be done actively or passively. Watching television is an example of passive relaxation. Others feel that relaxing is like an activity; they go to a yoga session or meditate. During a relaxation session like yoga, different techniques for relaxation can be used (i.e. Bernardi et al., 2001a; Borgeat, 1983; Peng et al., 2004; Zeier, 1984). Some meditation techniques use rhythms to make people feel relaxed or relieved. The 5Ryhthms meditation technique devised by Gabrielle Roth (2011) is a clear example of rhythms used for meditation practices. With this technique, people have to move intuitively on 5 musical styles with different rhythms. Another rhythmic relaxation tool in yoga is paced breathing. With paced breathing techniques, people have to breathe along with a auditory or visual stimulus to slow down their breathing rate (Peng, et al., 2004). Research has shown that rhythmic breathing in yoga or meditation is often at a respiratory rate of 6 cycles per minute (Peng, et al., 2004; Zeier, 1984). For example Bernardi and colleagues (Bernardi et al., 2001b) found that the recitation of the rosary prayer Ave Maria and the repetition of the yoga mantra “om-mani-padme-om” both result in a respiratory rate of 6 cycles per minute.

1.1 Paced breathing

Paced breathing influences bodily responses like skin conductance level, muscle tension and heart rate (Zeier, 1984). A respiratory rate of 6 cycles per minute can result in heightened Heart Rate Variability (HRV). Heart rate goes up during inhaling whereas heart rate goes down during exhaling. HRV is the difference between these two heart rate frequencies. Several studies have shown that breathing at 6 cycles per minute results in a higher HRV (Bernardi, et al., 2001a; Peng, et al., 2004; Vaschillo, Vaschillo & Lehrer, 2006). Increased HRV caused by a slow respiratory rate is known as Respiratory Sinus Arrhythmia (RSA). It has been shown that RSA has beneficial health effects and can for example result in a reduction of medication intake in people suffering from asthma (i.e. Lehrer, Lu & Siddique, 2004; Zeier, 1984).

Some companies have already recognized the power of breathing and developed devices to guide people towards a slow paced breathing. RESPeRATE, StressEraser and emWave are examples of so-called biofeedback devices, which claim to guide respiration to a healthy breathing rate (emWave, 2009; RESPeRATE, 2010; Stress Eraser, 2010). For example, RESPeRATE uses both auditory and visual feedback to show how fast people should breathe to affect health. It has been shown that the use of RESPeRATE for at least 15 minutes per day for at least 8 weeks results in a decrease of blood pressure in people who suffer from hypertension compared to a control group who listened to relaxing music for the same time (Elliot & Izzo, 2006). So it seems that a device which helps to practice paced breathing can reduce stress, just like the old methods of yoga and meditation do.

People can reduce subjective stress with respiration rate as well. In a review by Boiten, Frijda & Wientjes (1994) it is described that voluntary reduction of breathing speed can reduce subjective indices of anxiety. Paced breathing can also reduce self-rated tension, state anxiety (Clark & Hirschman, 1990) and anxiety level and arousal (McCaul, Solomon & Holmes, 1979). Eisen, Rapee and Barlow (1990) showed, for example, that paced breathing can result in a relaxation response. The participants in this study were tested on relaxation in a meditation session. One half of the participants had to breathe at a rate of 10 cycles per minute and the other half of the participants had to breathe 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. These results indicate that a slow paced breathing can be used to relax people.

James-Lange Theory can explain the subjective effects of paced breathing (Kalat, 2009). The theory proposes that emotions are an interpretation of bodily responses. If someone experiences something, it results in a cognitive evaluation of the situation and a bodily response. James-Lange Theory states that the interpretations of the bodily responses are emotional feelings. For example, Boiten and colleagues (1994) describe in their literature review, that it has been found that people increase their respiration rate when they experience negative emotions. According to James-Lange Theory the experienced negative emotion is a result of the increased respiration speed. Since slow breathing is related to a state of relaxation, James-Lange Theory would argue that people will feel relaxed when they decrease breathing speed during the experience of negative emotions.

1.2 Rhythms

Research has shown that respiration can be influenced by rhythms without actively synchronizing with them. One example of unconscious adjustment of respiration is the experiment done by Rassler and Raabe (2003), in which people unconsciously synchronized their breathing rate with the swings of a chair they sat on. This indicates that movement of the whole body can make people adjust their breathing rate towards a provided rhythm. Voluntary rhythmic body movements influence respiration rhythm as well. The best known breathing adjustment is the changed breathing rhythm while running (Bernasconi & Kohl, 1993).

Earlier research suggests that conscious adaptation of respiration can be guided by visual and auditory stimuli. For example, Zeier (1984) found that exhalation guidance through auditory signals combined with meditative thoughts results in a slower heart rate compared to participants who were only told to relax. Mena Benito and colleagues (2008) and Weda and Tijs (2009, July; 2009, September; 2010, January) showed that people can synchronize their breathing rate with a visual rhythm. In their paced breathing studies, they used a Philips Ambilight television screen as visual guiding stimulus. The television was adapted to provide visual feedback through the lighting behind the screen. Their results indicate that some people are able to follow a visual rhythm with their breathing and relax, and others are not. Rambaudi and colleagues (2007) found similar results on the optimal lighting pattern of a visual respiration guidance system.

Auditory rhythmic stimuli can also influence breathing rate unconsciously. Research about respiration and music has shown that people breathe at different rates with different types of music. Music with a faster beat induces a faster breathing compared to the respiratory rate without listening to music. However, silence after music results in even slower breathing, which seems to create even more relaxation than music with a slow beat (Bernardi, Porta & Sleight, 2006).

Unintentional synchronization is also a natural phenomenon between people interacting. Past research shows that people are highly influenced by interpersonal rhythms like clapping of an audience. Néda, Ravasz, Vicsek, Brechet and Barabási (2000) found that when an audience starts to clap, people start to clap in synchrony after some time. This synchrony is expected to occur by feedback from the sound of the clapping of other people. Another example of spontaneous interpersonal synchronization is visually driven. The literature study of Oullier and Kelso (2009) describes that interpersonal movement patterns are dependent on the ability to see another person and appear without people instructing to do so.

Although auditory rhythms seem to be dominant in conscious movement synchronization like finger tapping tasks (Repp & Penel, 2004), visual rhythms influence to a greater extent when they are provided slower. However, we don't know much about unconscious influences of visual rhythms on unconscious synchronization yet. Studies using the "moving room" paradigm show that people can react on visual changes unconsciously. In the classical experiments about this paradigm, people had to rest in a fixed frame when the walls of the room were moving and therefore suggested motion. The summary of the current findings by Schöner (1991) describes that the visual motion of the walls can induce postural sway in the direction of the visual motion and that, more importantly, rhythmic motion has the largest effect at low frequencies (about 0.1 Hz). Since most natural lighting rhythms are also quite slow, the optimal speed of changing light to influence bodily functions might be much slower than the ones studied in finger tapping studies (i.e. Aschersleben, 2002). When visual rhythms are created through lighting, other bodily functions than postural sway might be influenced by it. Likewise, respiration is a relatively slow, changeable body rhythm, which can be guided by slow visual rhythms (Mena Benito, et al., 2008; Rambaudi, et al., 2007; Weda & Tijs, 2009, July, 2009, September, 2010, January). Because people are well able to synchronize with lighting rhythms, unconscious influencing respiration through visual changes may also be possible. However, no research in the field of synchronization of respiration and visual rhythms has been done.

1.3 The current research

The studies about paced breathing show the effect of conscious, active synchronization of respiration and rhythmic visual changes (i.e. Mena Benito, et al., 2008; Rambaudi, et al., 2007; Weda & Tijs, 2009, September). However, whether visual stimuli might also be able to influence breathing rhythms unconsciously has not been investigated. The goal of our studies is to find what the influence is of rhythmic changes in lighting on breathing rhythm and relaxation, with and without conscious synchronization instructions. In the first experiment we try to replicate earlier findings (i.e. Rambaudi, et al., 2007; Weda & Tijs, 2010) to show that people are able to synchronize their breathing with a visual rhythm consciously. In our experiment we use changes in illuminance of lighting of spots instead of lighting from a television to create a more peripheral stimulus. These changes are shown to be perceived in the periphery of vision (Perz, 2010; Sarter, 2006) and are not expected to interfere with a task. We expect that people can synchronize with rhythmic lighting when they actively try to and that therefore respiration can be slowed down. We also expect that because of the slow breathing, the rhythmic lighting will be experienced as subjectively relaxing, since reported stress is closely related to respiration (i.e. Eisen, et al., 1990). As a result of the slowed respiratory rate, we expect that heart rate will go down and that galvanic skin response will decrease faster and with fewer peaks with rhythmic lighting compared to static lighting (Boucsein & Backs, 2000).

If it is possible to influence respiration unconsciously, slowing down of respiration can induce relaxation in a nonintrusive manner. This can be used in the design of new systems which support the relaxation process of people at home and can be used in other more stressful environments such as hospitals. The results of the present studies will contribute to a better understanding of the influence of rhythmic lighting on respiration and relaxation.

2 Experiment 1

2.1 Method

Participants were exposed to a static lighting setting and to a rhythmic lighting setting while conducting a mental arithmetic task and synchronizing their respiration with the lighting rhythm consciously. Their bodily responses were measured during the whole session and after each lighting condition, subjective relaxation was measured. Participants were assigned randomly to the different order conditions. All experiments took place between 14.30h and 17.30h.

2.1.1 Design

The experiment was a 2x2 design with two lighting settings (static vs. rhythmic) as independent within-variable and order as independent between-variable. The static lighting setting contained lighting which did not change in illuminance and the rhythmic lighting setting contained lighting which changed gradually in illuminance over time. The dependent physiological measures were heart rate, respiratory rate and skin conductance level. Subjective relaxation was measured in amount of stress, arousal and relaxation.

2.1.2 Participants

Ten employees or interns from Philips Research (5 female, aged between 21 and 28 years, M = 25.6, SD = 1.96) participated in the experiment.

2.1.3 Apparatus

The visual instructions of the experiment were displayed on a 32” Philips Ambilight Television screen. The instructions were shown on the screen using an automatically running PowerPoint presentation, automatically starting the movies and sound samples. Sound was provided by the same television. All responses were written down on a piece of paper. The experiment took place in the apartment of the Experience Lab of Philips Research in Eindhoven, which is a reproduction of a typical Dutch living environment (Figure 1).

The participants were attached to a Mind Media Nexus-10 measuring device to measure bodily responses. Respiration, heartbeat, and galvanic skin response were measured using this device. Besides the responses of the participants, the illuminance of the lighting in the environment was measured with a light intensity detector.

Figure 1: Overview of the apartment in the Experience Lab of Philips Research

2.1.4 Lighting

The lighting consisted of two standing lamps and six halogen spots in de ceiling (Figure 2). The standing lamps contained Philips Master TL5HE linear fluorescents of 28 Watt and the halogen spots were PHILIPS VA7 of 50 Watt. The lighting settings were chosen based on visibility and pleasantness.

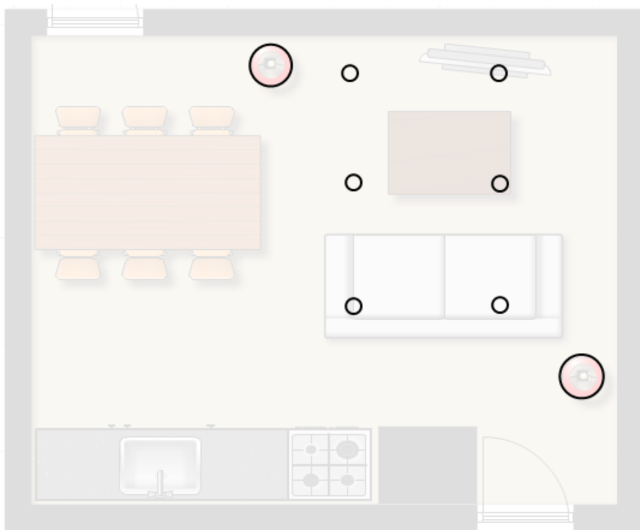

Figure 2: Location of the lighting in the apartment of the Experience Lab of Philips Research

In the static lighting setting, the standing fluorescents lighted continuously with a power of 11.0 Watt and the spots lighted continuously with a power of 19.7 Watt. In the rhythmic lighting setting, the standing fluorescents lighted continuously with a power of 11.0 Watt. The spots lighted with a minimum power of 17.8 Watt and a maximum of 21.7 Watt. The speed of the rhythmic changes was 0.1133 Hz and followed the changes in lung volume of a normal tidal breath (Levy, Koeppen & Stanton, 2006), as can be found in Figure 3.

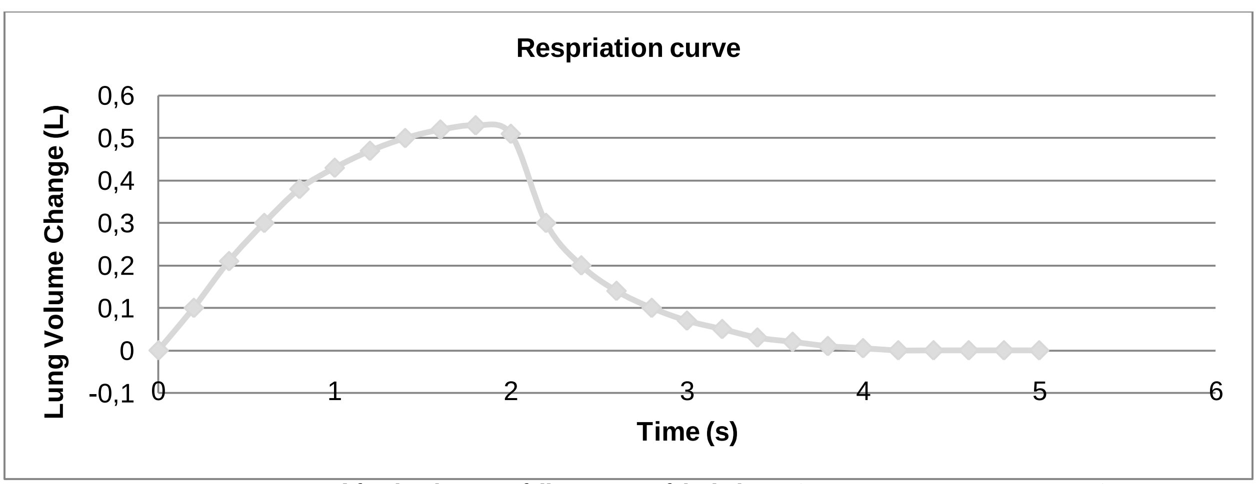

Figure 3: Respiration curve as used for the changes of illuminance of the lighting (Levy, Koeppen & Santon, 2006)

2.1.5 Dependent measures

For the analysis of respiration, average respiration cycle time (RCT) was analyzed. RCT is defined as the average time of one inhalation and exhalation during the total movie or task. The average time difference between two successive peaks (of maximum inhalation) in the respiration signal was taken as RCT value.

For the analysis of the heartbeat signal, average inter beat interval (IBI) was analyzed. IBI is defined as the average time of one cardiac cycle during the total movie or task. The average time difference between two successive peaks in the heartbeat signal was taken as IBI value.

For the analysis of the galvanic skin response, two measures were taken: the average derivative of the galvanic skin response (SGSR) and the average amount of peaks in the galvanic skin response (PGSR). SGSR is defined as the average derivative of the galvanic skin response during the total movie or task. PGSR is defined as the average amount of peaks per second of galvanic skin response during the total movie or task.

For the analysis of subjective stress, the average value of the stress items of the SACL was taken. This value for stress was calculated after removing the item "contented". This makes our STRESS-scale a 5-item scale consisting of "tense", "up-tight", "calm", "uneasy" and "relaxed". In this analysis, all answers on the SACL from all participants in experiments 1 and 2 were combined. The value for stress is the total sum of the values of “calm” and “relaxed”, and the reverse values of “tense”, “up-tight” and “uneasy”, divided by 5. Cronbach's α for stress scale of the SACL is 0.71.

For the analysis of subjective arousal, the average value of the arousal items of the SACL was taken. For the calculation of Cronbach's α, all answers on the SACL from all participants in experiments 1 and 2 were combined. The value for arousal is the total sum of the values of “active”, “energetic” and “lively”, and the reverse values of “drowsy”, “sluggish” and “sleepy” divided by 6. Cronbach's α for the arousal scale of the SACL is 0.87.

For the analysis of relaxation on the Visual Analogue Scale, the distance from the left side of the scale to the indicated value was measured with a ruler.

2.1.6 Procedure

Participants were welcomed and seated on the couch. They were given a written introduction of what the experiment would be and they were asked to sign the informed consent form. The Mind Media Nexus-10 measuring device was attached to the body with help of the experimenter and the incoming signal was checked. The experimenter repeated that instructions would be given by the screen and showed the participants where all forms and the button on the Nexus-10 could be found. Then the experimenter started the presentation and left the room.

After the first instructions on the screen, the participant watched the first baseline movie about life under water (Hannan, 1992) with a viewing distance of about 220 centimeters. The movie was used in previous experiments as recovery or relaxation stimulus (Colamussi, Bovbjerg & Erblich, 2007; Riek, Rabinowitch, Chakrabarti & Robinson, 2009). Then, the first mental arithmetic task started. The task was a mental arithmetic task like the easy task used by De Rammelaere, Stuyven & Vandierendonck (2001). In the current study, participants had to write down the answer of the sums on a piece of paper. The duration of the mental arithmetic task was 8 minutes and all sums consisted of one-digit numbers and included addition and subtraction. These sums were generated randomly and were provided with a recorded voice. The string of sums did not contain any rhythm and the time between the sums was between 5 and 10 seconds. The addition-subtraction ratio was 5:2, during the second task the ratio was 3:2. During the mental arithmetic task, the lighting was static or rhythmically changing. In the rhythmic lighting setting, participants were instructed to actively breathe in synchrony with the rhythmically changing lighting, in the static lighting condition, participants did not get any instruction about breathing. After the mental arithmetic task the participants were asked to fill out the first checklist. This checklist was because of time issues a shortened version of the original version of the Stress and Arousal Checklist (Mackay, Cox, Burrows & Lazzerini, 1978) modified with a 7 point Likert scale. The checklist contained the six items with the highest factor loadings on stress ("tense", "up-tight", "calm", "contented", "uneasy" and "relaxed") and the six items with the highest factor loadings on arousal (“active”, “energetic”, “lively”, “drowsy”, “sluggish” and “sleepy”), similarly used by Wilson and Kerr (1999). The form also asked the participant to rate their current state of stress/relaxation on a 10cm Visual Analogue Scale as used previously by Norton, Holm & McSherry II (1997) to measure on subjective relaxation. Participants were given 2 minutes to complete the checklist, while a countdown clock was shown on the screen. Thereafter, the participant was told to pick up a second checklist from the other side of the room. The short walk was included to interrupt any breathing patterns resulting from the first condition and to make participants breath naturally again. When the participants sat down on the same spot as before, another chapter of the baseline movie was shown. Again after the movie, a second mental arithmetic task started with the rhythmic lighting setting or static lighting setting, dependent on order condition. After the task, the second checklist had to be filled out. Shortly afterwards, the experimenter entered the room and conducted a short funneled debriefing interview (based on Chartrand & Bargh, 1996) to find out if the participants had any idea about the purpose of the experiment. During the first general questions of the interview, the participants detached themselves from the Mind Media Nexus-10 measuring device. The funneled debriefing interview contained open questions and questions which were measured on a 7 point Likert scale. Finally, the participants were asked to fill out a form with demographic information. Participants were thanked and debriefed. All forms can be found in Appendix A. The procedure is visualized in Figure 4.

Attach Nexus + Introduction	Movie	Task	Checklist	walk	Movie	Task	Checklist	Funneled debriefing

Figure 4: Overview of procedure

2.2 Results

The average values of the physiological data can be found in Appendix B.

2.2.1 Respiration

First, we expected that participants would slow down their breathing rate towards the speed of the lighting rhythm. A repeated measures analysis revealed a significant difference between the lighting settings for average RCT, $F(1, 8) = 9.88$, $p < .05$. The RCT was longer during the rhythmic lighting setting ($M = 5.33$, $SD = 0.54$), compared to the static lighting setting ($M = 3.83$, $SD = 0.30$).

Second, we expected that participants were able to synchronize breathing with the lighting rhythm. Exploration of the individual data shows that three out of ten participants were able to adjust their respiration towards the provided rhythm of the lighting for short intervals (Figure 5). Their RCT was about 7.2 seconds which was close to the provided rhythm of 8.8 seconds per cycle. No analysis was done to quantify the synchronization because of the small amount of participants who were able to adjust their RCT towards the cycle time of the lighting.

An additional analysis revealed that the effect of rhythmic lighting found on the slowed respiration rate was due to the people who were able to synchronize with the lighting rhythm. The effect totally disappears when these people are removed from the analysis, despite that six of the seven participants increased RCT, $F < 1$.

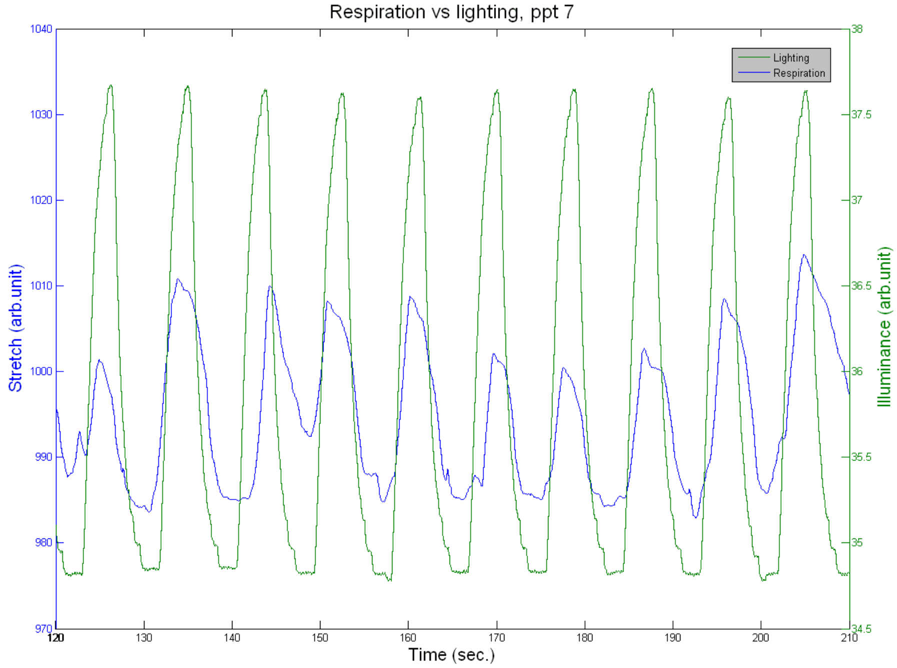

Figure 5: Example of a part of the breathing pattern of one participant breathing in synchrony with the provided lighting rhythm. Blue line = relative respiration pattern measured with a band around the chest, green line = relative lighting illuminance measured with a light intensity detector.

Ppt nr	Static lighting	Rhythmic lighting
1	4.12	4.71
2	3.37	4.08
3	3.81	7.16
4	6.50	5.80
5	3.40	4.95
6	3.94	6.16
7	3.66	7.15
8	3.68	7.22
9	3.49	3.62
10	2.52	2.60

Table 1: Individual RCT times in seconds in the two lighting conditions

2.2.2 Heart beat

We expected that IBI would be higher in the rhythmic lighting setting compared to the static lighting condition. The results show that there is no difference in IBI between the rhythmic and static lighting setting, $F < 1$.

2.2.3 Galvanic skin response

We expected that SGSR would be more negative in the rhythmic lighting setting compared to the static lighting condition. The results show that there was no difference in SGSR between the rhythmic and static lighting setting, $F < 1$.

We expected that PGSR would be lower in the rhythmic lighting setting compared to the static lighting condition. The results show that there was no difference in PGSR between the rhythmic and static lighting setting, $F < 1$. A repeated measures analyses showed a trend interaction effect of lighting setting and order condition on PGSR, $F(1, 8) = 4.33$, $p < .1$, at the difference between the first and second baseline movie (Figure 6). This effect shows that compared to the first baseline movie, PGSR is higher in the second baseline movie after the static lighting setting (first baseline movie: $M = 1.50$, $SD = 2.38$; second baseline movie: $M = 2.86$, $SD = 3.75$), and is lower in the second baseline movie after the rhythmic lighting setting (first baseline movie: $M = 4.58$, $SD = 3.31$; second baseline movie: $M = 2.97$, $SD = 1.79$). This means that in general people are more relaxed after the rhythmic lighting condition and more stressed after the static lighting condition.

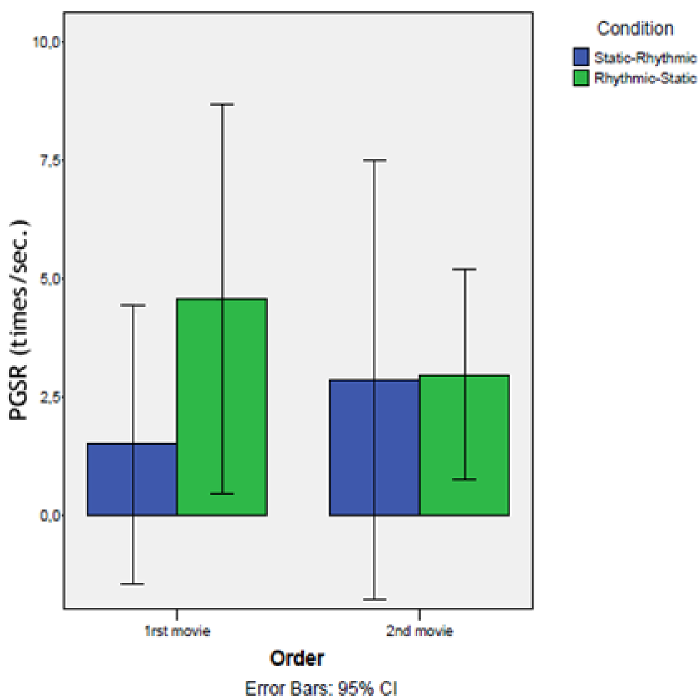

Figure 6: Interaction effect of movie order and condition on PGSR

2.2.4 Stress and Arousal Checklist

We expected that subjective stress would be lower in the rhythmic lighting setting compared to the static lighting condition. The results show that there is no difference in subjective stress between the rhythmic and static lighting settings, $F < 1$.

We expected that subjective arousal would be lower in the rhythmic lighting setting compared to the static lighting condition. Lighting settings had a significant influence on reported amount of arousal, $F(1, 8) = 5.84$, $p < .05$. Participants reported higher arousal levels after the rhythmic lighting setting (M = 4.67, SD = 1.22), compared to after the static lighting setting (M = 3.72, SD = 1.05). This means that people felt more aroused after the rhythmic lighting setting than after the static lighting setting. However, this effect was because of the participants who were able to synchronize well with the rhythmic lighting. A comparison of the participants who were able to synchronize breathing with the lighting rhythm to those who were not, revealed different reported amounts of arousal, $F(1, 8) = 3,39$, $p < .1$. Participants who were able to synchronize, reported higher amount of arousal (M = 4.95, SD = 1.92) compared to the participants who were not able to synchronize well (M = 3.87, SD = 2.93). This indicates that people who were synchronizing with the lighting rhythm felt more aroused than the people who did not synchronize.

2.2.5 Visual Analogue Scale

We expected that participants would report more relaxation in the rhythmic lighting setting compared with the static lighting setting, but the results show that there is no difference in relaxation on the VAS between the rhythmic and static lighting settings, $F < 1$.

2.2.6 Funneled debriefing

The funneled debriefing revealed that participants liked the lighting settings significantly different, $F(1, 9) = 5.21$, $p < .05$. Compared to the rhythmic lighting setting (M = 4.40, SD = 1.58), participants liked the static lighting setting (M = 5.50, SD = .71) better. This means that the static lighting setting was preferred over the rhythmic lighting setting. This effect is significantly influenced by the participants who were able to synchronize breathing with the lighting rhythm, $F(1, 9) = 10.82$, $p < .05$. Analysis of the data revealed that participants who were able to synchronize breathing reported less preference for the rhythmic lighting setting (M = 2.67, SD = 2.08), compared to the participants who were less able to synchronize breathing (M = 5.14, SD = .39). This means that the participants who were not able to synchronize breathing with the lighting rhythm did like the rhythmic lighting setting as much as the static lighting setting, whereas the participants who did synchronize breathing well with the lighting setting disliked the rhythmic lighting.

2.2.7 Order effects

Analysis of IBI data shows a significant effect of order, $F(1, 8) = 17.64$, $p < .01$. This effect shows that participants in the first lighting condition had a shorter average IBI ($M = 0.92$, $SD = 0.10$) compared to the second lighting condition ($M = 0.97$, $SD = 0.09$), independent of lighting setting. This means that participants were generally more relaxed in the second lighting setting compared to the first lighting setting.

2.3 Discussion

The goal of experiment 1 was to find if people are able to follow a lighting rhythm with their breathing and relax in this lighting setting. We showed that 3 out of 10 people were able to slow down their breathing speed towards the speed of a lighting rhythm to some extent when they were asked to. This means that synchronization is not an easy task for everyone. However, people who were able to synchronize breathing with the lighting rhythm report that subjective arousal increases. This effect of increasing arousal could be caused by the fact that the participants had to execute two tasks at the same time: breathe in synchrony with the lighting and doing a mental arithmetic task. Although people who were able to synchronize breathing with the lighting rhythm reported heightened arousal after the breathing task, the general results over all participants showed a relaxation response on the amount of peaks in galvanic skin response. The measurements during the second baseline movie showed that people who did the breathing task had a decreased amount of peaks in galvanic skin response whereas the people without synchronizing their breathing had an increased amount of peaks. These results showed that rhythmic lighting, combined with a paced breathing exercise can overcome stress resulting from a mental arithmetic task. It could even induce extra relaxation because the effects of the paced breathing and the task were in the opposite direction. However, this effect was not found in the averages during the task, which might indicate that a paced breathing task combined with rhythmic lighting needs some time to have an effect on other physiological measures. Another explanation for this finding is that participants were relieved that they did not have to execute a dual task in a changing lighting environment anymore. The results of the funneled debriefing also revealed that synchronizing respiration with rhythmic lighting was not liked by the people who were able to synchronize breathing with the rhythmic lighting. This might indicate that rhythmic lighting is not the ideal stimulus to guide a paced breathing, but might be useful for other purposes, because it was not experienced differently from the static lighting and created a relaxation response in galvanic skin response. However, results from galvanic skin response have to be interpreted very carefully, since it is a very unstable measure.

3 Experiment 2

3.1 Introduction

Experiment 1 showed that some people are able to synchronize their respiration with an external lighting stimulus. The amount of peaks in galvanic skin response was lower after the rhythmic lighting setting, which indicates that a rhythmic lighting setting is more relaxing than the static lighting setting. This means that it is possible to influence the physiological relaxation response through lighting. Previous research has shown that light and visual stimuli in the periphery of vision can influence people. For example, Hameed, Ferris, Jayaraman and Sarter (2009) showed that in specific situations participants are better able to react on peripheral visual or tactile cues compared to visual cues shown in their visual working environment. However, peripheral vision is only suited to detect motion, luminance changes and appearances of new objects, whereas it cannot recognize objects or details (Sarter, 2006).

Because of these findings, we want to test whether people synchronize with a lighting rhythm in the periphery without instructions to synchronize. The main task is expected to distract participants enough to not actively experience the changes in the lighting. The rhythmic lighting is therefore expected to result in an unconscious synchronization response. We expect that respiration will be slowed down unconsciously and that the slow rhythmic lighting setting will be experienced as relaxing. As a result of the slowed respiratory rate, we also expect that heart rate and galvanic skin response will go down with rhythmic changing lighting compared to static lighting.

3.2 Method

Participants were exposed to static lighting setting and to rhythmic lighting setting while conducting a mental arithmetic task. Their bodily responses were measured during the whole session and after each lighting condition, subjective relaxation was measured. . Participants were assigned randomly to the different order conditions. All experiments took place between 14.30h and 17.30h.

3.2.1 Design

The experiment was a 2x2 design with two lighting settings (static vs. rhythmic) as independent within-variable and order as independent between-variable. One lighting condition contained lighting which did not change in illuminance and the other lighting condition contained lighting which changed gradually in illuminance over time. The order of the exposure to the lighting settings was counterbalanced between participants. The dependent physiological measures were heart rate, respiratory rate and skin conductance level. Subjective relaxation was measured in amount of stress, arousal and relaxation.

3.2.2 Participants

29 employees or interns from Philips Research (12 female, aged between 20 and 55 years, *M* = 32.8, *SD* = 11.0) participated in the experiment.

3.2.3 Apparatus, lighting and procedure

The apparatus, lighting and procedure were exactly the same as the in experiment 1. The only difference was that in this experiment the participants were not instructed to synchronize breathing with the rhythmical changes in lighting.

3.3 Results

The processing of the raw data was done in the same way as in experiment 1. In the analyses of the physiological data, the averages measured during the first baseline movie were taken as a baseline and analyzed as covariate variable. The average values of the physiological data can be found in Appendix B.

3.3.1 Respiration

Controlling for group differences revealed that there was a significant difference in RCT during the first baseline movie between the different order conditions, $F(1, 25) = 5.25$, $p < .05$. So during the first baseline movie, the participants in the static-rhythmic lighting condition had a shorter RCT (*M* = 3.55, *SD* = 0.72), compared to the participants in the rhythmic-static lighting condition (*M* = 4.37, *SD* = 1.06). This means that participants in the static-rhythmic lighting condition breathed faster at the start of the experiment compared to the participants in the rhythmic-static lighting condition.

We expected that participants would slow down their breathing rate towards the speed of the lighting rhythm. The results of a repeated measures analysis showed in an interaction effect that RCT changes differently for both conditions, $F(1, 22) = 5.71$, $p < .05$. RCT during the first baseline movie (*M* = 4.23, *SD* = 0.95) was longer than during the task (*M* = 3.82, *SD* = 0.66) in the rhythmic lighting condition, $F(1, 12) = 6.16$, $p < .05$, whereas in the static lighting condition, the RCT during the first baseline movie (*M* = 3.52, *SD* = 0.74) was not different from during the task (*M* = 3.61, *SD* = 0.52). This means that, according to respiration speed, participants started to breathe faster in the rhythmic lighting condition compared to the baseline movie, whereas participants in the static lighting condition did not change their breathing speed compared to the baseline movie (Figure 7).

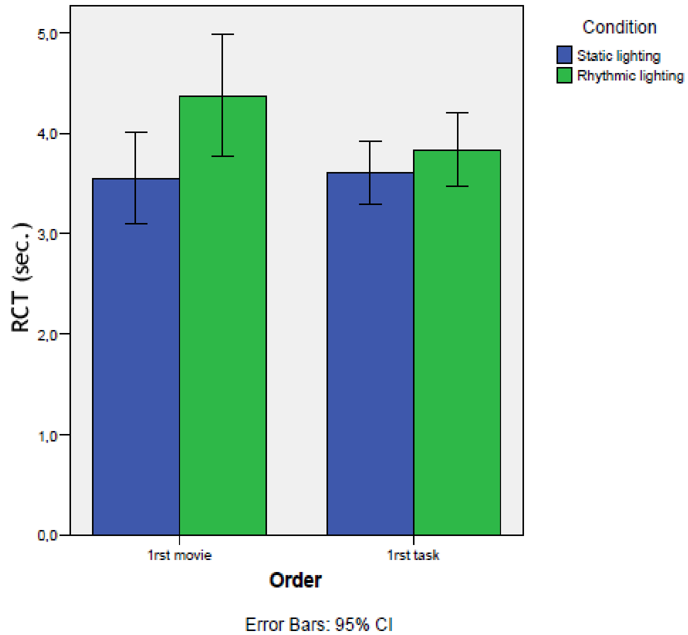

Figure 7: Interaction effect of order and lighting setting on RCT.

We also expected that participants were able to synchronize respiration with the lighting rhythm. The results show that RCT of all participants was too small to indicate synchronization.

3.3.2 Heart beat

We expected that IBI would be higher in the rhythmic lighting setting compared to the static lighting condition. The results show that there was no difference in IBI between the rhythmic and static lighting setting, $F < 1$.

3.3.3 Galvanic skin response

We expected that SGSR would be more negative in the rhythmic lighting setting compared to the static lighting condition. The results show that there was no difference in SGSR between the rhythmic and static lighting setting, $F < 1$.

We expected that PGSR would be lower in the rhythmic lighting setting compared to the static lighting condition. The results show that PGSR is different in both lighting conditions during the first task, $F(1, 23) = 5.72$, $p < .05$. PGSR was less during the static lighting setting ($M = 1.97$, $SD = 1.34$) compared to during the rhythmic lighting setting ($M = 4.63$, $SD = 2.94$). This means that participants were more relaxed in the static lighting setting compared to the rhythmic lighting setting based on the amount of peaks in galvanic skin response.

3.3.4 Stress and Arousal Checklist

We expected that stress would be less in the rhythmic lighting setting compared to the static lighting condition. Lighting settings did not have a significant main effect on reported amount of stress. There seemed to be a trend effect of condition, $F(1, 26) = 3.52$, $p < .1$, since participants in the static-rhythmic lighting condition generally reported more stress ($M = 1.55$, $SD = 0.18$), compared to the rhythmic-static lighting condition ($M = 1.08$, $SD = 0.17$). This means that participants in the static-rhythmic lighting condition felt more stressed compared to the participants in the rhythmic lighting condition.

We expected that arousal would be less in the rhythmic lighting setting compared to the static lighting condition. Results show that lighting settings did not have a significant influence on reported amount of arousal, $F < 1$.

3.3.5 Visual Analogue Scale

We expected that participants would report more relaxation in the rhythmic lighting setting compared with the static lighting setting, but lighting settings did not have a significant influence on reported amount of relaxation on the Visual Analogue Scale, $F < 1$.

3.3.6 Funneled debriefing

The funneled debriefing revealed that participants liked the lighting settings significantly different, $F(1, 23) = 10.51$, $p < .01$. Compared to the rhythmic lighting setting ($M = 3.67$, $SD = 1.58$), participants liked the static lighting setting ($M = 5.00$, $SD = 1.22$) better. This means that the static lighting setting was preferred over the rhythmic lighting setting.

3.3.7 Order effects

Extra analyses revealed significant order effects of RCT, IBI, SGSR and PGSR. A repeated measures analysis showed a significant interaction effect of order and lighting settings on average RCT, $F(1, 21) = 4.83$, $p < .05$. This effect shows that the first lighting condition has a shorter average RCT (S-R: $M = 3.69$, $SD = 0.50$; R-S: $M = 3.83$, $SD = 0.63$) compared to the second lighting condition (S-R: $M = 3.74$, $SD = 0.64$; R-S: $M = 3.94$, $SD = 0.67$). This means that participants were more relaxed in the second lighting setting compared to the first lighting setting, dependent on order condition (Figure 8).

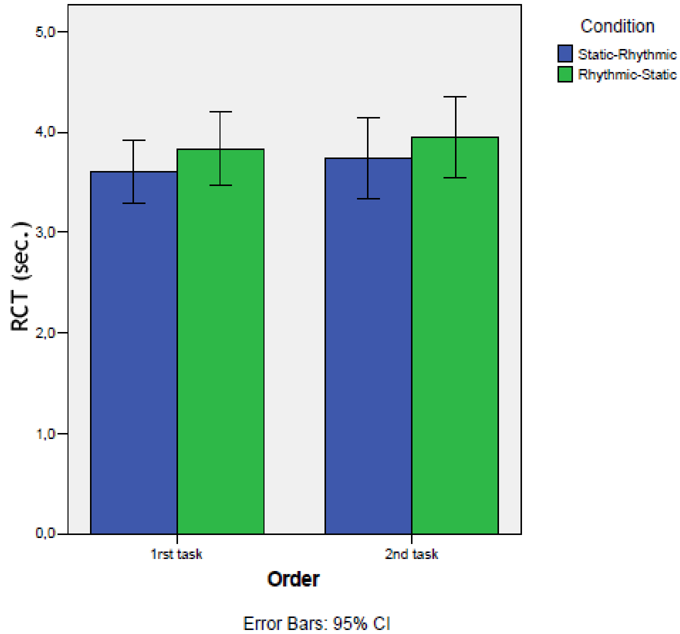

Figure 8: Influence of order on RCT

Analysis of IBI shows a significant effect of order, $F(1, 21) = 5.14$, $p < .05$. This effect shows that participants in the first lighting condition had a shorter average IBI ($M = 0.88$, $SD = 0.14$) compared to the second lighting condition ($M = 0.90$, $SD = 0.13$), independent of lighting setting. This means that participants were generally more relaxed in the second lighting setting compared to the first lighting setting.

A repeated measures analysis showed a significant order effect on SGSR, $F(1, 21) = 5, 34$, $p < .05$. This effect shows that SGSR is more negative in the second lighting condition ($M = -0.0000078$, $SD = 0.0000120$) than in the first lighting condition ($M = -0.0000030$, $SD = 0.0000077$), independent of lighting setting. This means that participants generally relaxed faster in the second lighting setting compared to the first lighting setting.

A repeated measures analysis showed the trend of an interaction effect of order and condition on PGSR, $F(1, 21) = 3.81$, $p < .1$. This effect shows that PGSR becomes higher in the second task of the static-rhythmic lighting condition (first: $M = 1.97$, $SD = 1.34$; second: $M = 3.20$, $SD = 2.00$), whereas it is the same over tasks in the rhythmic-static lighting condition (first: $M = 4.03$, $SD = 2.95$; second: $M = 4.01$, $SD = 3.53$). This means that participants became less relaxed when they experienced the static lighting setting first and the rhythmic lighting settings second, whereas participants did not change in relaxation when they experienced the rhythmic lighting setting first and the static lighting settings second (Figure 9).

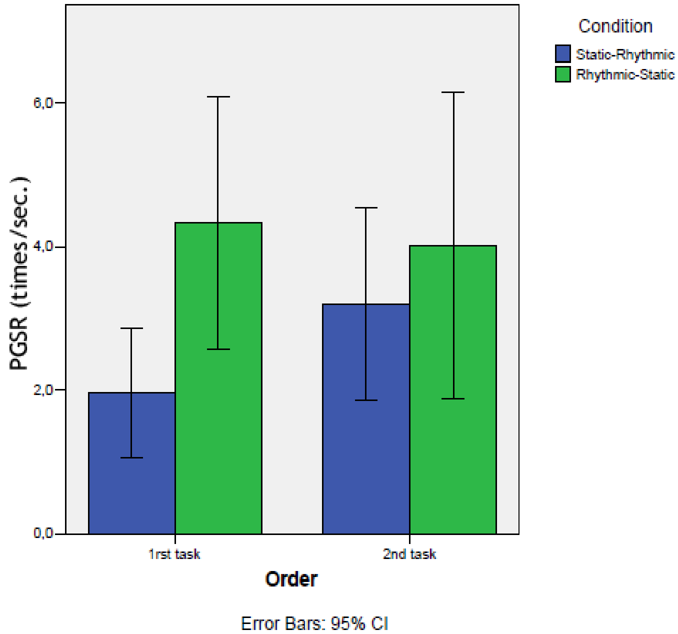

Figure 9: Interaction effect of order condition and lighting setting on PGSR

3.4 Discussion

The goal of this study was to find if people would unconsciously follow a lighting rhythm with their breathing and relax in this lighting setting. It was shown that people did not synchronize unconsciously with a lighting rhythm and they did not relax in a lighting setting with rhythmical lighting. The physiological measures showed that the lighting settings affected breathing speed and the amount of peaks in galvanic skin response. Breathing speed increased in the condition with the rhythmic lighting setting whereas it did not change in the static lighting setting between the first baseline movie and the first mental arithmetic task. This shows that people responded differently on the different lighting settings and showed increasing stress in the rhythmic lighting setting. The measurements of the amount of peaks in galvanic skin response indicated the same; this value was higher during the rhythmic lighting setting compared to during the static lighting setting, which indicates higher stress levels. The responses on the SACL on stress indicated that people experienced the two order conditions differently, because the static-rhythmic order showed a trend of higher reported stress compared to the rhythmic-static order condition. This might indicate that a new stimulus influences the way people perceive a task, and if the stimulus is unexpected, stress is higher. This effect could also be found in the interaction effect for amount of peaks in galvanic skin response where participants in the rhythmic-static order condition showed no change in amount of peaks, whereas the amount of peaks increased over the tasks for the participants in the static-rhythmic order condition. This indicated that the order of the lighting settings is important, because the stressful effect of rhythmic lighting stayed over time and conditions. The order effects on breathing, heart rate and galvanic skin response showed that people became more relaxed over time during the experiment. This effect of relaxation might have been caused by the lighting, the low excitement of the task or the couch.

4 General discussion

These studies examined the effect of rhythmic lighting on conscious and unconscious relaxation responses. Experiment 1 attempted to replicate earlier findings to show that people are able to synchronize their breathing with a visual rhythm (i.e. Rambaudi, et al., 2007; Weda & Tijs, 2009, July). In our experiment we used changes in illuminance of lighting for the synchronization of breathing. In experiment 2, we tried to influence people with a lighting rhythm without explicitly instructing them to synchronize breathing.

The results of experiment 1 demonstrate that some people are able to synchronize their breathing with a slow lighting rhythm for short intervals. People physiologically relax while synchronizing breathing with rhythmical changing lighting, but also report higher arousal. The results of experiment 2 indicate that people do not synchronize with a slow lighting rhythm unconsciously, but increase breathing speed instead. In this second study, people became more stressed by the rhythmic lighting on other physiological measures as well.

Although some people were able to synchronize their respiration consciously in experiment 1, synchronization did not occur unconsciously in experiment 2. There are several explanations for why people did not synchronize with the lighting rhythm unconsciously.

4.1 Rhythm

First, the speed of the lighting changes might have been too slow to react on unconsciously, because of the big difference between their natural breathing rhythm and provided lighting rhythm. In our experiments the lighting rhythm was more than half the average breathing speed of our participants. This difference might have been too big to overcome and to synchronize with. The lighting rhythm might need to be about the same speed as the natural breathing rhythm to result in unconscious synchronization. Second, the speed of the lighting rhythm might have been to slow to be recognizable as a breathing rhythm and might have been too unobtrusive to influence unconsciously. Kelso, Fink, DeLaplain and Carson (2001) showed that automatic synchronization of finger tapping with an auditory rhythm only occurs when the speed of the rhythmic stimulus is above a minimum speed. This means that a rhythm needs to contain enough visibility and rhythmical information to influence people unconsciously. In our study, the information about the rhythmicity of the lighting rhythm might have been too low to be still recognizable as breathing rhythm.

Another possibility is that people do not breathe rhythmically at all. A closer look at the respiratory data revealed that people breathe rhythmically only for short intervals, because of internal responses as sighing and external causes as disturbing noises. This is in line with studies about synchronization of clapping of audiences (Néda, et al., 2000). In these studies, people synchronized and desynchronized their clapping continuously. This might indicate that synchronization of natural rhythmic movements can only occur for short intervals and that overall synchronization will never occur. So, if people do not breathe in a systematic and rhythmic way, the provided lighting rhythm might have been too rhythmic to be followed naturally and breathing can probably not be influenced by any type of rhythm. This has several implications for future research and a different approach towards synchronization with lighting rhythms needs to be taken. Visual rhythms may work better in an associative process of “breathing light” instead as breathing synchronization guide. If lighting can create an affective response of a “breathing” environment, it might relax people without synchronizing respiration. However, more research is needed to investigate the processes of associative “breathing” lighting.

To overcome the problems of recognition of lighting rhythms, people may need to be trained to perceive a lighting rhythm correctly. Auditory rhythms are a natural phenomenon and are perceived very rhythmical. Although lighting is a natural phenomenon, lighting rhythms are not common and might not be perceived as rhythmic so easily. There might be a cognitive process involved which makes that people need to learn to perceive a rhythm correctly, before synchronization can occur in the first place. Since auditory rhythms are everywhere around us, they are perceived well because people are confronted with them a lot. As shown in the research by Aschersleben (2002), people with a strong musical background show less asynchrony than lay people in a finger tapping task using an auditory rhythm. Aschersleben also found that people need feedback about their asynchrony to become able to exactly synchronize with a rhythmic auditory stimulus. If this process of learning is the same for synchronization of respiration and lighting rhythms, people need to get used to a lighting rhythm and need time to practice synchronization. For the current area of research, unconscious synchronization of breathing with a lighting rhythm can be tested again after people are perfectly able to follow a lighting rhythm consciously.

4.2 Stress

The results of our experiment show that the illuminance changes combined with the mental arithmetic task created a stress response in people. The lighting rhythm might have resulted in two opposite internal processes: relaxation through synchronization of breathing and stress because of uncomfortable feelings. The stress might have resulted from the changes in lighting. In our experiment we chose to change the illuminance of lighting, because these changes are shown to be perceived in the periphery of vision (Perz, 2010; Sarter, 2006). As already shown by Bernardi and colleagues (2006), a faster musical rhythm leads to more physiological arousal, whereas slower musical rhythms result in relaxation. If this is also works for visual rhythms, visual rhythms need to be slow enough to result in relaxation. Since fast changes of light are uncommon, the changes in lighting might have been too fast to be perceived as natural and were therefore disturbing and stress inducing. People might have been more vigilant in the testing environment, which resulted in more arousal and therefore faster breathing. They could even have closed their eyes to get away from the disturbing lighting rhythm if they wanted to and could therefore not be influenced by the lighting rhythm. A slower or less visible lighting rhythm might have resulted in more relaxation, but more research is needed to investigate this topic. Because changes in motion can be recognized by peripheral vision and can influence people unconsciously (Schöner, 1991), it might change physiological processes more than rhythmic changes in illuminance do.

4.3 Mental arithmetic task

The main limitation of the current experiments was the used task. We used an adapted form of a mental arithmetic task which was used before in experiments with a dual task (Imbo, Vandierendonck & Vergauweke, 2007). In experiment 1, the task probably interfered with the breathing task, because people seemed unable to synchronize with the lighting rhythm while executing a mental arithmetic task. In experiment 2, the participants did not have to pay attention to the rhythm of the lighting and might have been mainly focused on the task itself. Although it was expected that people would unconsciously react because of a distracting main task, this did not happen. Therefore it is recommended to reconsider the mental arithmetic task or to use a task which is more common in a living room. However, research about the pure effects of rhythmic lighting without a task should be done first.

4.4 Conclusions

The current research suggests that rhythmic changes in illuminance of lighting can influence people. It seems to be able to make people slow down breathing when they try to consciously, but can make them feel more aroused at the same time. This suggests that rhythmic lighting might not be suited to slow down breathing speed unconsciously; it seems to have made people physiologically more aroused instead. The effects of rhythmic lighting are hard to interpret because of the interplay of stress and relaxation responses and more research in the area of rhythmical changing lighting is needed. A start can be made with the investigation of the most influencing lighting intensities and speeds of rhythm. Whereas our research shows that rhythmical changes in lighting lead to more arousal, the challenge is to find suiting rhythmical lighting for relaxation purposes.

5 References

Aschersleben, G. (2002). Temporal Control of Movements in Sensorimotor Synchronization. *Brain and Cognition, 48*, 66-79.

Bernardi, L., Porta, C. & Sleight, P. (2006). Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence. *Heart, 92,* 445-452.

Bernardi, L., Sleight, P., Bandinelli, G., Cencetti, S., Fattorini, L., Wdowczyc-Szulc, J., et al. (2001a). Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study. *British Medical Journal, 323*(7327), 1446-1449.

Bernardi, L., Sleight, P., Bandinelli, G., Cencetti, S., Fattorini, L., Wdowczyc-Szulc, J., et al. (2001b). Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study. *Britisch Medical Journal, 323,* 1446-1449.

Boiten, F. A., Frijda, N. H. & Wientjes, C. J. E. (1994). Emotions and respiratory patterns: review and critical analysis. *International Journal of Psychophysiology, 17*, 103-128.

Borgeat, F. (1983). Psychophysiological effects of two different relaxation procedures: progressive relaxation and subliminal relaxation. *Psychiatric journal of the University of Ottawa, 8,* 181-185.

Boucsein, W. & Backs, R. (2000). Engineering Psychophysiology as a Discipline: Historical and Theoretical Aspects. In R. Backs & W. Boucsein (Eds.), *Engineering psychophysiology*. Mahwah: Lawrence Erlbaum Associates, Inc.

Chartrand, T. L. & Bargh, J. A. (1996). Automatic activation of social information processing goals: Nonconscious priming reproduces effects of explicit conscious instructions. *Journal of Personality and Social Psychology, 71*, 464-478.

Clark, M. E. & Hirschman, R. (1990). Effects of paced respiration on anxiety reduction in a clinical population. *Biofeedback and Self Regulation, 15*, 273-284.

Colamussi, L., Bovbjerg, D. H. & Erblich, J. (2007). Stress- and Cue-Induced Cigarette Craving: Effects of a Family History of Smoking. *Drug and Alcohol Dependence, 88*, 251–258.

De Rammelaere, S., Stuyven, E. L. S. & Vandierendonck, A. (2001). Verifying simple arithmetic sums and products: Are the phonological loop and the central executive involved? *Memory & Cognition, 29*, 267-273.

Eisen, A. R., Rapee, R. M. & Barlow, D. H. (1990). The effects of breathing rate and pCO2 levels on relaxation and anxiety in a non-clinical population. *Journal of Anxiety Disorders, 4,* 183-190.

Elliot, W. & Izzo, J. (2006). Device-Guided Breathing to Lower Blood Pressure: Case Report and Clinical Overview. *Medscape General Medicine, 8*. Retrieved from http://www.medscape.com/viewarticle/539099 emWave. (2009). emWave Personal Stress Reliever. Retrieved 16 Febuary, 2011, from www.heartmathbenelux.com

Hameed, S., Ferris, T., Jayaraman, S. & Sarter, N. (2009). Using Informative Peripheral Visual and Tactile Cues to Support Task and Interruption Management. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 51*, 126-135.

Hannan, D. (Writer). (1992). Coral Sea Dreaming - An Evolving Balance.

Imbo, I., Vandierendonck, A. & Vergauweke, E. (2007). The role of working memory in carrying and borrowing *Psychological Research 71*, 467-483.

Kalat, J. W. (2009). *Biological Psychology* (10th ed.). Belmont: Wadsworth.

Kelso, J. A. S., Fink, P. W., DeLaplain, C. R. & Carson, R. G. (2001). Haptic information stabilizes and destabilizes coordination dynamics. *Proceedings of the Royal Society of London B 268*, 1207-1213.

Lehrer, P., Lu, S. & Siddique, M. (2004). Biofeedback Treatment for Asthma. *CHEST, 126,* 352-361.

Levy, M. N., Koeppen, B. M. & Stanton, B. A. (2006). *Berne & Levy Principles of Physiology*. Philadelphia: Elsevier Mosby.

Mackay, C., Cox, T., Burrows, G. & Lazzerini, T. (1978). An inventory for the measurement of self-reported stress and arousal. *British Journal of Social and Clinical Psychology, 17*, 283-284.

McCaul, K., Solomon, S. & Holmes, D. (1979). Effects of Paced Respiration and Expectations on Physiological and Psychological Responses to Threat. *Journal of Personality and Social Psychology, 37*, 564-571.

Mena Benito, M., Krans, J. & Rajae-Joordens, R. (2008). *RelaxTV: User test on first research prototype*. Koninklijke Philips Electronics N.V.: Technical Note PR-TN 2008/00228.

Néda, Z., Ravasz, E., Vicsek, T., Brechet, Y. & Barabási, A. L. (2000). Physics of the rhythmic applause. *Physical Review E, 61*, 6987.

Norton, M., Holm, J. E. & McSherry II, W. C. (1997). Behavioral assessment of relaxation: The validity of a Behavioral Rating Scale. *Journal of Behavior Therapy and Experimental Psychiatry, 28*, 129-137.

Oullier, O. & Kelso, J. A. S. (2009). Social coordination from the perspective of coordination dynamics. In R. A. Meyers (Ed.), *Encyclopedia of complexity and systems sciences* (pp. 8198-8212). Berlin: Springer-Verlag.

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

Perz, M. (2010). *Flicker perception in the periphery*. Eindhoven: TU Eindhoven.

Rambaudi, L., Rossi, E., Mántaras, M., Perrone, M. & Siri, L. (2007). Visual aided pacing in respiratory maneuvres. *Journal of Physics: Conference Series, 90*, 1-6.

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*, 125-130.

Repp, B. & Penel, A. (2004). Rhythmic movement is attracted more strongly to auditory than to visual rhythms. *Psychological Research, 68*, 252-270.

RESPeRATE. (2010). RESPeRATE To Lower Blood Pressure. Retrieved 17 September, 2010, from www.resperate.com

Riek, L. D., Rabinowitch, T., Chakrabarti, B. & Robinson, P. (2009). *Empathizing with Robots: Fellow Feeling along the Anthropomorphic Spectrum*. Paper presented at the IEEE Conference on Affective Computing and Intelligent Interaction (ACII 09), Amsterdam, Netherlands.

Roth, G. (2011). 5Rhythms global. Retrieved 11 February, 2011, from www.gabrielleroth.com

Sarter, N. (2006). Multimodal information presentation: Design guidance and research challenges. *International Journal of Industrial Ergonomics, 36*, 439-445.

Schöner, G. (1991). Dynamic theory of action-perception patterns: the “moving room” paradigm. *Biological Cybernetics, 64*, 455-462.

Stress Eraser. (2010). Official Stress Eraser. Retrieved 17 September, 2010, from www.stresseraser.com

Vaschillo, E., Vaschillo, B. & Lehrer, P. (2006). Characteristics of Resonance in Heart Rate Variability Stimulated by Biofeedback. *Applied Psychophysiology and Biofeedback, 31*, 129-142.

Weda, H. & Tijs, T. (2009, July). RelaxTV: test 1 [PowerPoint slides]. Philips Research Laboratories.

Weda, H. & Tijs, T. (2009, September). RelaxTV: test 2 [PowerPoint slides]. Philips Research Laboratories.

Weda, H. & Tijs, T. (2010, January). RelaxTV: test 3 [PowerPoint slides]. Philips Research Laboratories.

Wilson, G. V. & Kerr, J. H. (1999). Affective responses to success and failure:: a study of winning and losing in competitive rugby. *Personality and Individual Differences, 27*, 85-99.

Zeier, H. (1984). Arousal Reduction with Biofeedback-Supported Respiratory Meditation. *Biofeedback and Self-Regulation, 9*, 497-508.

Appendices

Appendix A

Introduction

Welcome to the experiment about atmosphere perception! I am very happy that you take part in the experiment for my graduation project. All information will be used and stored anonymously.

The goal of this experiment is to acquire information about the perception of lighting atmospheres in a living environment. You are about to experience different lighting settings in which you do some different tasks; you will watch a movie and do some easy calculations. The TV screen will show you what to do at which time. On the table in front of you, you will find the different forms you need during the experiment.

During the experiment you will be attached to a Nexus-10 measuring device. This device will measure heart rate, respiration and skin conductance. These measurements will be used to analyze the reactions of your body on the different lighting settings.

If you have any questions, please feel free to ask them.

Inge Brandt

INFORMED CONSENT RnC2

Volunteer

- √ I had sufficient time to consider my participation in this project and I am fully aware that my participation in this project is voluntarily.
- √ I know that I can decide not to participate of stop my participation at any time without giving any reason for this decision.
- √ I understand and agree that my personal data will be collected, used and processed, for the purposes of the research project, by the responsible researcher and other parties that are involved in the research project. The personal data to be collected may be related to my health. I understood that my directly identifying personal data (e.g. name, address) will be separated from the research data and replaced by an assigned number/code. Access to the key/link between the assigned number and my identity will be limited to the responsible researcher and might only be disclosed to the independent medical advisor in case of medical need.
- √ I agree to the use of my personal data for other research and development purposes.
- √ I know that I have the right to request an overview of my personal data that have been collected about me and can have it corrected or deleted.
- √ I agree to participate as a volunteer in this research project.

_________________________ _____________________ ___________

Name Signature Date

Responsible researcher

I have answered all questions about the research project and discussed the meaning and scope of this informed consent and signed it in the presence of the volunteer.

_________________________ _____________________ ___________

Name Signature Date

Form A

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Checklist 1

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best. On the table you can find an explanation for each statement.

		1	2	3	4	5	6	7
		Not at all		**A little**		**Somewhat**		**Very Much**
1.	**I feel tense**	1	2	3	4	5	6	7
2.	**I feel relaxed**	1	2	3	4	5	6	7
3.	**I feel active**	1	2	3	4	5	6	7
4.	**I feel energetic**	1	2	3	4	5	6	7
5.	**I feel drowsy**	1	2	3	4	5	6	7
6.	**I feel uneasy**	1	2	3	4	5	6	7
7.	**I feel up-tight**	1	2	3	4	5	6	7
8.	**I feel lively**	1	2	3	4	5	6	7
9.	**I feel contented**	1	2	3	4	5	6	7
10.	**I feel sluggish**	1	2	3	4	5	6	7
11.	**I feel sleepy**	1	2	3	4	5	6	7
12.	**I feel calm**	1	2	3	4	5	6	7

Please rate your current relaxation/stress level on the scale below:

Very tense ●————————————————● very relaxed

Funneled debriefing

What did you think of the experiment?

What did you like? (come up with 3)

What did you dislike? (come up with 3)

What do you think this experiment was trying to influence?

What do you think this experiment was trying to find?

What did you think of the nature movie?

What did you think of the task?

How demanding was the task?

Not at all	1	2	3	4	5	6	7	Extremely

Can you explain why?

How much did you like the static lighting?

Not at all 1 2 3 4 5 6 7 Extremely

When you were doing the task, did you experience anything unusual about the lighting?

Yes/No/Maybe/I don't know

If yes/maybe, what exactly?

How much did you like the rhythmic lighting?

Not at all 1 2 3 4 5 6 7 Extremely

Did you recognize a specific rhythm in the lighting?

Yes/No/Maybe/I don't know

If yes/maybe, what kind of rhythm?

How much did you feel the lighting affected you during the task?

Not at all 1 2 3 4 5 6 7 Extremely

If yes, how exactly?

How much did you relax?

Not at all 1 2 3 4 5 6 7 Extremely

If yes, why do you think you relaxed?

How much did you change your breathing rhythm during the experiment?

Not at all 1 2 3 4 5 6 7 Extremely

If yes, how?

How much did you actively adjust your breathing to the rhythm of the lighting?

Not at all 1 2 3 4 5 6 7 Extremely

Did you feel that you relaxed because you slowed down your breathing to the rhythm of the lighting?

Yes/No/Maybe/I don’t know

Do you have any additions or notations to this interview? Things that I did not ask and you want me to know, which may be important?

Thank you very much for you participation.

I would like to ask you not to talk about the experiment with other people.

Debriefing

The influence of rhythmic changes in lighting on relaxation.

November-December 2010

Thank you for your participation in this research about rhythmic changes in lighting and relaxation. The purpose of this study is to find the influence of rhythmic changes in lighting on the amount of relaxation. It was hypothesized that your breathing will adapt to the rhythm of the lighting and that the lighting will be experienced as relaxing. This is expected, because it is shown that rhythms have the ability to slow down respiration so it can be used to induce relaxation. If the hypotheses are shown to be true, the results can be used to create relaxing environments.

You were led to believe that the purpose of this study was atmosphere perception of white light. This deception was necessary because any awareness of breathing leads to a different breathing pattern and therefore has to be prevented. If you feel uncomfortable about your data being used for this purpose, you are free to withdraw your data from the sample.

I would like to ask you not to talk about the experiment to other people, because they may participate in the experiment as well. The experiment is running until the end of December and I want all participants to be as naïve as possible, because any knowledge about the study being about breathing may change the results.

Contact Information

If you have questions right now, please ask. If you have additional questions later, you may always contact me or my supervisor Hans Weda. If you would like to get more information about the results of the study, you can also contact me or my supervisor.

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Appendix B

Descriptives of experiment 1

	Static RCT	Rhythmic RCT	Static IBI	Rhtyhmic IBI	Static SGSR	Rhythmic SGSR	Static PGSR	Rhythmic PGSR
N	10	10	10	10	10	10	10	10
Mean	3, 85	5, 34	, 95	, 94	-, 0000065	-, 0000124	3, 69	4, 35
Std. Error of Mean	, 32	, 51	, 032	, 03	, 0000040	, 0000060	, 974	1, 24

Descriptives of experiment 2

	Static RCT	Rhythmic RCT	Static IBI	Rhtyhmic IBI	Static SGSR	Rhythmic SGSR	Static PGSR	Rhythmic PGSR
N	25	26	24	10	24	25	24	25
Mean	3, 78	3, 79	, 90	, 94	-, 0000063	-, 0000034	3, 08	3, 83
Std. Error of Mean	, 12	, 12	, 03	, 03	, 0000025	, 0000018	, 59	, 53