Brease: Airflow as a Tactile Interface for Breathing Exercises

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ABSTRACT

Cognitive Behavioral Therapy is the most widely used psychological form of treatment for Insomnia. In this study the attempt is made to determine the effectivity of enhanced breathing exercises using airflow as an interface.

Using the HRV frequency method for determining stress reduction as an objective manner and the Relaxation Rate Scale and State-Trait Anxiety Inventory as a subjective indicator for relaxation. 12 participants were asked to do a breathing exercise with feedforward and airflow and 14 participants did an exercise with biofeedback and airflow. From our HRV data analysis we were able to conclude that there was a decrease in arousal in participants after performing the second breathing exercise which included the airflow interface. We are unable to conclude if this was due to carryover learning factors or due to the addition of our airflow system. It also remains unclear whether tactile Biofeedback is more effective than tactile feedforward in reducing arousal.

Author Keywords

Airflow; Relaxation; Respiration; HRV; Biofeedback; Insomnia;

INTRODUCTION

Insomnia

Insomnia is a serious issue where persistent problems arise with the quality or quantity of sleep. Many people do experience some fluctuation in the amount of sleep they receive and some people need more sleep than others. Insomnia takes it a step further. 30% of all people experience insomnia symptoms for a short time, 4-20% of all individuals cope with long-lasting characteristics of the disorder. Chronic insomnia can have serious and far-reaching consequences, like increased rate of work absence, workplace accidents, motor vehicle accidents, use of health services and hospitalizations, a reduced quality of life and development of depressions [7].

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The disorder can have many causes, it might occur after significant life events or changes to a person’s sleep schedule or environment. Cognitive behaviour therapy for insomnia (CBT-I) is the most widely used and respected psychological treatment and consists of a number of different techniques: stimulus control therapy, sleep restriction therapy, cognitive therapy, relaxation strategies, and sleep hygiene [7].

The mindset of an insomnia patient exist of excessive worries and ruminations, which trigger autonomic arousal and emotional distress. The individuals is plunged into an anxious state [4]. With the model of Harvey (2002) it is believed that selective attention and monitoring needs to be reduced or banded in order to break the cycle of insomnia patients. Or in the case of this research, needs to be prevented to not become an insomnia patient at all.

Relaxation as part of CBT-I

One of the CBT-I techniques that is effective in countering this worry factor are the relaxation strategies component. Relaxation techniques include progressive muscle relaxation, breathing exercises, or guided imagery to reduce mental activity [7]. This research primarily focuses on breathing exercises, since this strategy is relatively easy to learn for inexperienced participants. Similar design research has been performed in these areas.

Two categories of breathing techniques can be distinguished, feedforward and feedback [2]. Breathing techniques based on feedforward are used to prescribe a breathing rhythm to the user. Feedback is a way of increasing mindfulness of breathing, and is a technique which offers us a lot of possibilities thanks to modern technologies. By using data collected from our bodies, we can give people more information about their inner processes and as a result make them more aware, this type of feedback is called biofeedback.

Biofeedback

Research in the field of biofeedback shows that certain types of breathing-based biofeedback can positively contribute to relaxation therapies [1,3], noteworthy is feedback based on heart rate variability (HRV).

Heart rate variability is the the beat-to beat difference in heart rate and is considered as an objective relaxation or stress indicator [8,9].

A high HRV correlates with relaxedness and is associated with the activity of the parasympathetic nervous system (rest-and-digest) and vise versa a low HRV correlates with stress and is associated with the activity of the sympathetic nervous system (fight-or-flight)[8].

One can artificially alter their heart rate variability by breathing, this process is called respiratory sinus arrhythmia (RSA). When breathing in, the heart rate goes up and when breathing out, the heart rate goes down [8].

A breathing rate of 6 breaths per minute produces predictably large increases in HRV at that frequency. HRV biofeedback encourages people to breathe at a frequency at which HRV and respiration are exactly in phase. This is usually near this 6 minute cycle (breaths/min). Therefore should biofeedback maximize the respiratory efficiency [11].

Related work

Mostly visual and auditory forms of biofeedback based on breathing have been explored. Typical biofeedback instruments present a real time graph of one's heart rate variability and breathing. "SonicCradle" uses a breathing sensor to control multiple layers of auditory feedback to create an immersive meditative experience [12]. "Breath with Touch" explored a tactile interface for breathing exercises. After the completion of a breathing training exercise with tactile feedforward a majority of participants showed an increase in heart rate variability (SDNN) [13].

This promising result left us with curiosity about tactile means of providing biofeedback. In this research we investigate to what extent airflow can be used as a form of tactile (respiratory) biofeedback. Our targeted demographic consists of young adults.

DESIGN AND IMPLEMENTATIONS

Design Concept

The concept "Brease" is a tactile interface for breathing exercises. Surrounding airflow changes direction as the user performs deep breathing exercises intended to improve focus and engagement. "Brease" enables participants to control the airflow in real-time by activating each fan in sequence. When the participant's chest expands, airflow is propelled toward the participant. When the chest contracts the direction is inverted to create the impression that the surrounding environment is breathing with you. The feeling is subtle to mimic a gentle breeze.

Figure 1. Setup: participant sitting between two air fans with equal distances, wearing a respiration belt and PPG sensor.

The developed system consists of two separate fan units and a respiration sensor. The sensor is essentially made up of a belt with an integrated conductive stretch cord which was placed on either the chest or upper abdomen. Next, the participant is asked to take a seat in comfortable chair with one unit positioned directly in front and the other fan unit placed behind the user, at a distance of approximately 0.5m. The height of the units is adjusted to a height matching the seated participant's upper body.

Method

In order to reduce the effect of potentially interfering factors, all tests have been conducted in our faculty's Biofeedback Lab. The environment is stable, particularly outside noise, temperature and the amount of light in the room. Changes in arousal are measured using a PPG sensor. The pulse signals are recorded by a data acquisition unit developed by our faculty. Beat to beat (RR) intervals are calculated and transmitted to a processing program for data storage. Standard deviation of the RR intervals are calculated as an indicator of HRV using data analysis software (HRVAS) [14].

According to the European Heart Journal (1996) [5] frequency domain methods are, in most cases, preferred when investigating short term recordings. The two components compared in our study are HF and LF requiring a minimum of 2 minutes to determine. It is stated that a period of five minutes is preferred when conducting a stationary recording and advised that data retrieved by the frequency method is more easily interpreted than the SDNN and RMSSD methods. HF and LF are suitable metrics for stress, therefore it can be stated that a decrease in stress correlates with a favorable relaxation method [10].

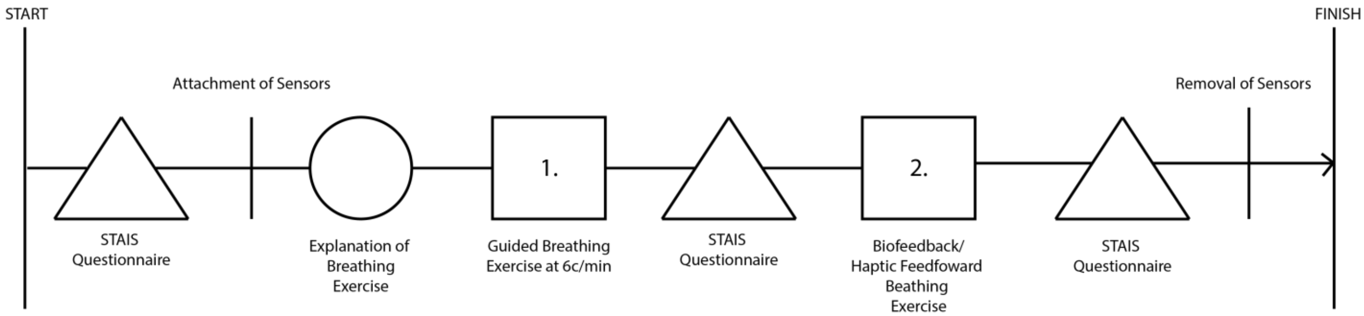

Figure 2. Experiment procedure

Breathing data is captured using a conductive rubber cord to provide data about chest expansion and contraction. The ANT system was used to record the respiratory data from the sensor belt.

The data from both sensory outputs are monitored throughout the test. The state component of the Spielberger State-Trait Anxiety Inventory (STAIS) was used to determine the participant's stress level, before, during and after the tests [6].

Our study was conducted in two groups. Each group was tested until ten sets of usable data were recorded. Three conditions were tested for a period of 5 minutes to ensure scientific validity. Condition one consisted of a baseline test where participants were asked to perform a breathing exercise at a fixed rate of six cycles per minute. Participants were given a visual and auditory queue every five seconds to inform them when to switch between breathing in and out. Condition two entailed the addition of tactile feedforward by way of airflow. The same breathing pattern was maintained, as well as the visual and auditory queues. The third condition had users breathe at a frequency of their choosing and provided tactile feedback to the user through our biofeedback system using respiration data as input. After a pilot test to determine the distance to the fan units and to ensure data acquisition went smoothly, Group A and B completed condition one and two, and one and three respectively. These data sets were analyzed and compared, yielding the following results.

RESULTS

Objective data

From the HRV sensor LF/HF ratio data could be retrieved. The HRV data from both group A and B each consisted of 11 valid samples from 5 female, 6 male and 11 male respectively. The two sample t test is conducted to find out the significance level of the change in HRV after the addition of tactile feedforward or biofeedback.

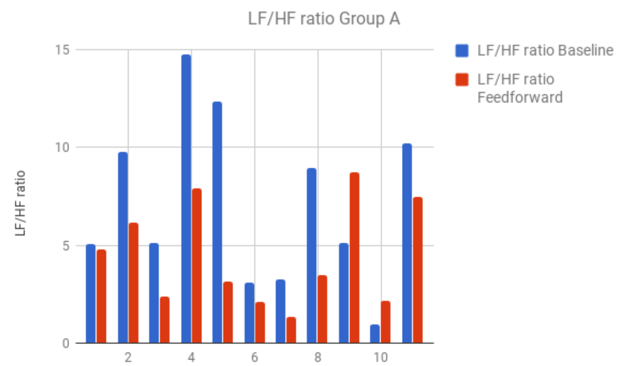

Figure 3. Group A, LF/HF ratios baseline and feedforward tests (N=11)

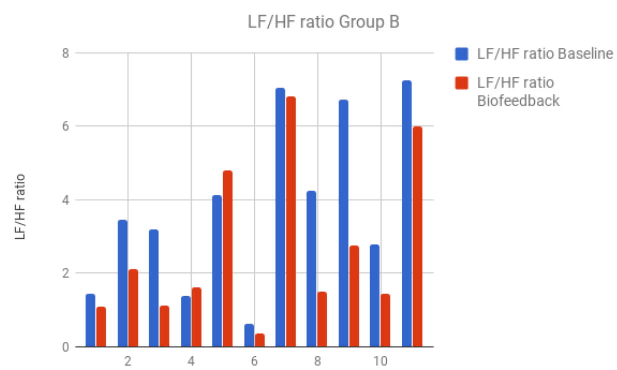

Figure 4. Group B, LF/HF ratios baseline and biofeedback tests (N=11)

The results as shown in figure 3 and 4 suggest that the addition of airflow either in the form of feedforward or feedback results in a decrease in LF/HF ratio. In both groups 9 participants exhibited a lower ratio during breathing exercises involving airflow, however the significance level doesn't reach the p value of $p < 0.05$ and thus requires a larger sample size for validation..

	Baseline	Biofeedback
Baseline	P=0.0371	P=0.2442
Feedforward	P=0.2070	P=0.0947

Table 1. Significance of LF/HF ratios between tests (P<0.05)

Subjective data

The subjective data is acquired by the use of two separate questionnaires: the State-Trait Anxiety Inventory and the Relaxation Rate Scale.

The Relaxation Rate Scale is a single question with a scale from 1 to 9 (1 not at all, 9 totally) asking the participants to indicate how relaxed they are at that specific moment.

The State-Trait Anxiety Inventory (STAI) is a questionnaire existing of 20 statements (short version, normally 40) in which the participants indicate how anxious they feel at that specific moment. The options vary from 1 to 4, where 1 is not at all and 4 is very much so. Two scales are integrated: the State Anxiety Scale (S-Anxiety), which are ten statements asking the participants how they feel right now. The other one is the Trait Anxiety Scale (T-Anxiety), which are ten statements about relatively stable aspects of ‘anxiety proneness’ [6]. In this case the S-Anxiety scores were turned to be able to calculate one total score for the questionnaire, presenting the participants anxiety decrease. This was done to see if the results of both questionnaires could be compared.

Both questionnaires can be found in Appendix D (with an indication of the interpretation of positive and negative statements).

The participants were asked to fill in both questionnaires before starting any experiment, after the baseline experiment (control group) and after their second breathing exercise (feedforward with airflow or biofeedback). The following data was retrieved from these questionnaires:

STAI

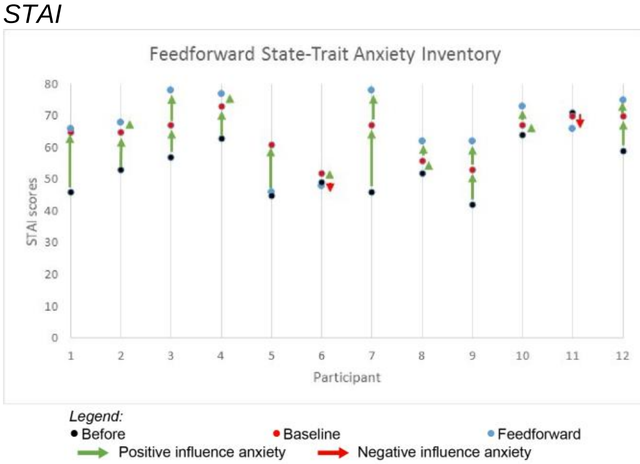

Figure 5. Group A, feedforward with airflow – STAI, N=12 (Note: participants 5 + 6 have invalid objective data)

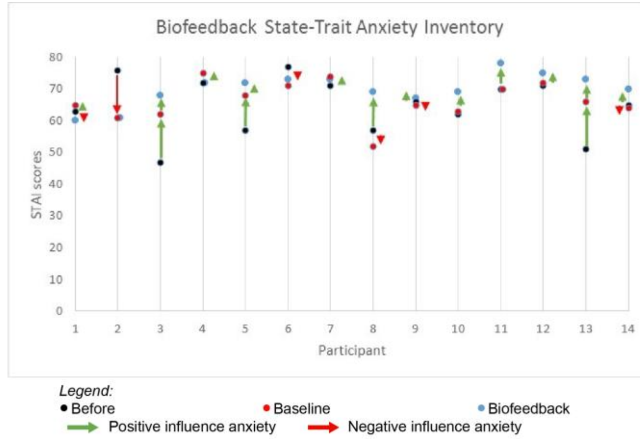

Figure 6. Group B, Biofeedback with airflow – STAI, N = 14 (Note: participants 1, 2, 6, 11 and 14 have invalid objective data)

Figures 5 and 6 show the results of the STAI per participant for the two different groups. Not all objective data is valid, however the subjective data can be used.

From figure 5 can be concluded that:

- 92% of the participants score higher on the STAI in the baseline condition, which means that visual feedforward and conscious focus on breathing helps with the participants decrease of anxiety in the relaxation process.
- 75% of the participants indicate that feedforward with airflow helps them to feel less anxious than in the baseline condition.

From figure 6 can be concluded that:

- 57% of the participants score higher on the STAI in the baseline condition, which means that visual feedforward and conscious focus on breathing helps them with decreasing their anxiety level.
- 64% of the participants indicates that biofeedback is even better than the baseline or start condition (in the case that the baseline scores lower than the start condition).

RRS

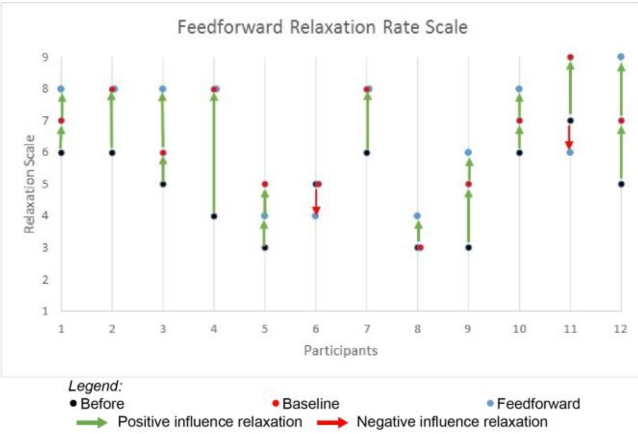

Figure 7. Group A, Feedforward with airflow – RRS, N=12 (Note: participants 5 + 6 have invalid objective data)

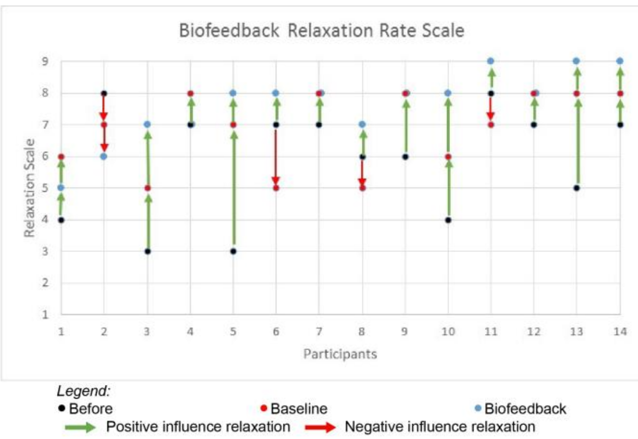

Figure 8. Group B, Biofeedback with airflow - RRS, N=14 (Note: participants 1, 2, 6, 11 and 14 have invalid objective data)

In figures 7 and 8 are the results shown of the RRS per participant of the two different groups. Not all the participants had valid objective data, but the subjective data can all be used. In the figures, the dots show the different questionnaires that the participants filled in, the colors present the times and the arrows show a negative or positive influence on the anxiety level.

From figure 7 can be concluded that:

- 83% of the participants indicated that they felt more relaxed after the baseline condition.
- 50% of the participants indicated that they felt even more relaxed after the addition of airflow.

From figure 8 can be concluded that:

- 71% of the participants indicated to be more relaxed after the baseline condition.
- 57% of the participants indicated to be even more relaxed after the baseline experiment or the start (in case the baseline scored worse than the start) with the addition of biofeedback with airflow.

Comparison questionnaires

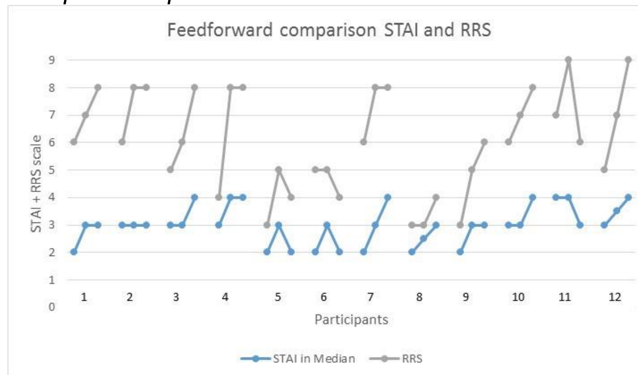

Figure 9. Group A, Feedforward with airflow - comparison STAI & RRS, N=12

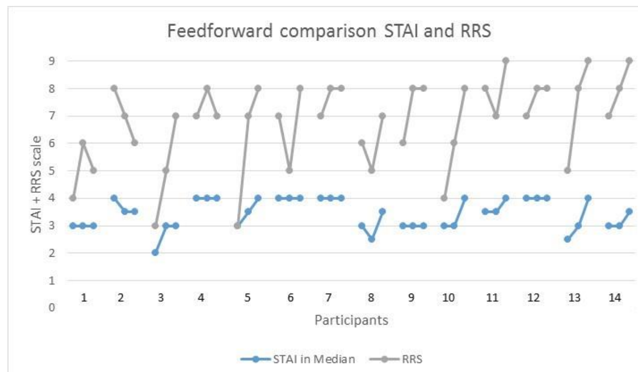

Figure 10. Group B, Biofeedback with airflow - comparison STAI & RRS, N=14

For figures 9 and 10 the median is taken for the STAI questionnaire and the RRS data is used to compare the results per participant. The first dot represents the before questionnaire, the second the baseline experiment, and the third the group specific test.

For figure 9 it can be concluded that the overall trends of the questionnaires are comparable.

For figure 10 however, it seems that the RRS shows more diversity than the STAI scale.

Significance

	Feedforward	Biofeedback	Significance level
Baseline	92%	57%	P=0.0490
	P<0.0001	P=0.0010	
Experiment	75%	64%	P=0.5530
	P=0.0002	P=0.0004	
	N=12	N=14	

Figure 11. STAI Significance level (P < 0.05 is significant)

	Feedforward	Biofeedback	Significance level
Baseline	83%	71%	P=0.4803
	P=0.0001	P=0.0001	
Experiment	50%	57%	P=0.7264
	P=0.0056	P=0.0010	
	N=12	N=14	

Figure 12. RRS Significance level (P < 0.05 is significant)

Through analysis of both questionnaires it can be concluded that the baseline condition scores higher on relaxation/ less anxiety for both experiments. This indicates that implementing visual feedforward by itself has a relaxing effect, which is proven to be significant in this experiment (p=0.0001, p=0.0001, p<0.0001 and p=0.0010).

Both experiments (Feedforward and biofeedback with airflow) score higher than the baseline or starting position (in case the baseline was received to be less relaxing/ anxiety increasing) in both questionnaires. This difference is also significant (p=0.0056, p=0.0010, p=0.0002 and p=0.0004). This means that airflow in general has an added value to relaxation.

The difference, however, between the use of biofeedback with airflow and feedforward with airflow is not significant in both questionnaires (p=0.7264 an p=0.5530).

DISCUSSION

Impressions of the chosen method of output, being airflow, vary. While some participants liked the sensation of the air moving towards them, others found it made it hard to relax completely.

Several factors could have had an effect on the outcome of our test. Most notable being the learning factor that is involved in these breathing techniques and the carry-over effect a five minute breathing exercise has on the subsequent test results. Another element that could have had an impact on the frequency data is the stress induced task of discovering how the system responds to the user's input. Perhaps it would have been more effective to allow the participants to acclimate for a longer period of time, thus decreasing the effect. In addition to increase the validity of the HRV data a preliminary sample could have been gathered from each participant before the baseline test to have a more accurate indication of the effect of airflow on respiration feedback/feedforward in comparison to the effect of a fixed respiratory rate of 6 cycles per minute.

The difficulty of creating a responsive airscape, the delay, and sound passing through the air units, as well as the sound of rushing air detracted some participants from the sensation we are trying to create. Placing the units at an angle could potentially yield more favorable results, however we chose not to in order to make the direction of the airflow more noticeable. Responses varied greatly. To some, the sound of the valves switching and the airflow was pleasant and allowed them to relax and clear their mind. To others the sound seemed as a distraction from the experience. The fixed rate breathing exercises were rather advanced, while some participants showed no signs of difficulty maintaining six cycles per minute, others found it hard to hold their breath in time for the feedforward to tell them to breathe. In retrospect, a shorter rhythm would have been preferable. Participants appeared to enjoy relaxing completely and waiting for the airflow to tell them when to breathe.

CONCLUSION

Results from the State Anxiety Index component of our study indicate that there is a significant decrease in anxiety after the breathing exercises are performed with tactile feedforward/feedback. However, there is no significant data to support an advantage of Biofeedback over haptic feedback, in the form of airflow, in our context. This result could be caused by a number of factors including imperfections in the design or the way in which the study was set up.

The Objective data derived from Heart Rate Variability measurements however did not point to a significant change in arousal. Although a pattern could be observed indicating a slight decrease in stress (LF/HF ratios) after the addition of tactile feedback/feedforward.

Both the subjective and objective data point towards a slight increase in effectiveness however the used sample sizes for determining a significant change in HRV and difference in effectivity of feedback and feedforward methods is not sufficient to validate our findings.

One relevant application could be a system integrated around the bedroom to help Insomnia patients maintain a steady breathing pattern by progressively slowing the rate of the airflow in order to peripherally reduce anxiety. Since the systems usability in small environments would be significantly improved due to a decreased proximity and airflow delay a future research opportunity could be the use of airflow as a tactile guidance/feedback method aimed at reducing stress in vehicular transportation. For example during the designing of autonomous cars an airflow pattern could be implemented to guide the riders to relax.

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ir. J.Lo – Insomnia
dr. S. Overheem – Insomnia

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