NAAVA

breathe

Quantified biophilia effects on stressful tasks

DO NAAVA SMART GREEN WALLS AFFECT OUR OXYTOCIN LEVELS?

Siru Heiskanen & Jarno Mikkonen

Naava
Laukaantie 4 40320 Jyvaskyla, FINLAND
jarno.mikkonen@naava.io

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INTRODUCTION

Oxytocin is a hormone produced by the hypothalamus, and released from the posterior lobe of the pituitary gland. Research shows that oxytocin inhibits anxiety (Uvnäs-Moberg et al. 1994, Windle et al. 1997), helps us relax, and reduces stress (Uvnäs-Moberg 1997, 1998), blood pressure (Petersson et al. 1996a), heart rate (Petersson & Uvnäs-Moberg 2007) and cortisol levels (Petersson et al. 1999). It increases pain thresholds (Petersson et al. 1996b), and stimulates various types of positive social interactions (McCarthy & Altemus 1997, Ferguson et al. 2000, Kosfeld et al. 2005). In addition, it even promotes growth and healing (Uvnäs-Moberg 1997, Detillion et al. 2004) and weight-loss (Petersson & Uvnas-Moberg 2008). Oxytocin is released by non-noxious sensory stimulation, such as touch, warmth, food, smells, sounds, and lights. Positive social behaviour such as hugging and empathy towards others (Barraza & Zak 2009) is also known to trigger oxytocin release, and our environment plays a role in it as well.

It is known that being in nature and having plants indoors increases creative working, mood, energy, and general well-being (Asaumi et al. 1995, Shibata & Suzuki 2002). In a study by Asaumi et al. (1995) it was found that improving the aesthetic quality of rooms with plants caused people to feel more relaxed compared to rooms with no plants or where they were replaced by screens. Healing effects of plants have been shown to include stress-buffering by decreased cortisol levels, decreased anger and hostility, and better vigor (Sawada & Oyaby 2010). It is also known that indoor air quality has an effect on performance and productivity (Wyon 2004). Our goal is to find out if Naava smart green walls affect the oxytocin levels in humans positively during a stress-inducing task.

Oxytocin levels are decreased with people suffering from depression, stress-related disorders, anxiety, and chronic pain. Promoting higher oxytocin levels could prevent such conditions. If Naava green walls are found to promote higher oxytocin levels during stressful tasks, we could conclude that the presence of Naavas can be linked to the health promoting benefits of higher oxytocin levels, and

they could be used as a natural way to increase oxytocin levels to prevent anxiety and stress, being especially beneficial in i.e. high-stress working environments and places of recovery, such as hospitals.

To find out whether Naava green walls have an impact on oxytocin levels in humans, we have created an initial research assembly as a trial test (more about the bigger experimental setting in the last chapter) which has two conditions: test subject participates in a stress-inducing task either in the control room that has no green wall, or in a room that has a green wall installed.

We expect to see that the participants who have been doing a task performance in room B with a green wall have a higher level of oxytocin than those in the control room. We expect that they also have lower blood pressure and higher heart rate variability, and that their skin temperature reflect induced stress and is less visible in subjects who took the task in room B. If the results seem promising, we upscale the research to include two other treatment rooms and a higher amount of test subjects. Other changes to the initial test can also be made at this point i.e. to the task. Two other treatment rooms included are to study the aesthetic and air quality effects of Naava green walls separately: room C where the green wall is placed behind/hidden from the subject, and room D where a replacement green wall (i.e. a window, plastic plants, a screen) is placed in front of the subject.

METHODS

The research was conducted at the Wilhelm Schildt's high school in Jyväskylä, Finland, during two days (28.2.–1.3.2017) on a winter holiday when no other people were present at the school. 12 voluntary test subjects were recruited via an e-mail notification, where recipients were told that they would receive movie tickets in exchange for participating in a two day study where their cognitive abilities would be tested while recording their autonomic nervous system. The real goal of the study was not revealed at any point during the testing.

The test subjects arrived four at a time to the school, where they first filled in a questionnaire addressing their age, sex, possible chronic diseases and athletic background. They then filled in a VAS (Visual Analogue Scale) questionnaire of mood, environmental comfort, anxiety,

and fear. After that, samples of blood and saliva were taken, heart rate monitors were put on, and the test subjects were then led to their experiment rooms. All of the rooms were located next to each other, and were regular school classrooms fundamentally identical to each other. Two of the rooms had a Naava greenwall, and two did not. Test subjects were seated in a similar position in each room, where they were facing a plain wall. The test rooms with Naava had them positioned to the side wall, one seat row away from the subject (picture 1). They were given instructions of the test, after which their external temperature was measured from the tip of their noses. Subjects performed a 5 minute deep breathing exercise, after which they got a sound cue to begin the test.

The word association test included 20 words, which the subjects had 10 minutes to fill in max 30 words they associated with each. After the time was up, they heard a sound cue and saliva samples were immediately collected as well as the same VAS questionnaire was filled. The blood samples were taken, after which they performed another 5 minute deep breathing exercise, and their temperature was measured again. On the second day of the experiment, subjects were placed on opposite rooms (with or without Naava) than on the previous day. All of the test subjects did the tests at the same time on both days. Four subjects performed the test at the same time in separate rooms and had no contact with each other. Due to chance, all but one test subject happened to be female. This should be considered when reporting the results. It is also possible that the subjects guessed the meaning of the study when seeing the green wall, and therefore might have placebo effects. After the tests, however, some subjects were asked if they realized what the actual study subject was, and had not realized it. Therefore we can assume that placebo is likely not to have an effect.

Analyses

The word association test and VAS questionnaire
H_0: Test subjects perform equally well in both rooms
H_1: Test subjects perform differently when in different rooms

Two tailed t-test for dependent samples was used to see whether the two samples are significantly different from each other. The same test was

also used to define the significance in the data between day 1 and day 2, and the mood questionnaire VAS-data.

As the test was written with ballpoint pens, any mistakes were easy to record. Mistakes were counted on the following bases: words with clear misspellings, corrections, or words that were crossed over or against the given instructions (for example, proper nouns instead of common nouns). No words were counted as mistakes based on their association to the given word, as those words did not occur and the concepts are subjective.

Skin temperature was measured with a thermal imaging camera from the tip of the nose (Flir K2, FLIR systems Inc., Oregon, USA). An average of three measurements was used. Temperature was measured before and after the stress test.

Raw R&R (interbeat interval) data for HRV analyses were collected using Polar V800 (Polar Electro Oy, Kempele, Finland) wrist computers. Subjects were advised to breathe calmly and count slowly to 5 during every inhale and exhale. These calm 5 minute episodes were conducted before and after the stress test and served as the the time frames for HRV analyses in Kubios HRV software (Kubios Oy, Kuopio, Finland).

Hormonal analyses were analysed from saliva and blood samples collected before and after the stress tests. All hormones were analyzed using ELISA (IBL ELISA kit for cortisol saliva (IBL International, Hamburg, Germany), Cayman ELISA kit for plasma oxytocin (Cayman Chemical, Michigan, USA) and ALPCO ELISA kit for saliva oxytocin (ALPCO, New Hapshire, USA). All extractions and preparations were performed according to each manufacturer's instructions.

RESULTS

General

11 of the 12 test subjects were female. No one had cardiovascular diseases or other chronic diseases, except for one with atopic skin. Four of the participants classified themselves in being in a stressful life

situation. Three classified themselves as physically active (training more than three times a week). All of the participants were young adults (aged 20-35).

The word association test

The total number of words, averages, medians, and standard deviations are listed in Table 1 for each of the sample groups: combined scores, first test day, second test day, control room (without Naava) and test room (with Naava).

There was *a statistically significant difference* in the number of words invented by each test subject *between the two experiment days* (n = 12, p = 0.00001): each of the test subjects improved their performance an average of 25.7 words. There was no significant difference in this improvement based on which room they did the test first: an average improvement of 26 words for those who started on a room without Naava, and 25.3 for those who started on a room with Naava (n = 6, p = 0.94). When comparing the results of the *two different rooms* (without/with Naava), *no difference was found* (n = 24, p = 0.97).

Table 1

Number of words

Group	Total	Average	Median	SD
Total	2240	93.3	89.5	23.7
Day 1	945	80.5	77.5	20.7
Day 2	1255	106.2	103	19.7
No Naava	1118	93.5	90.5	20.08
Naava	1122	93.2	88.5	27.8

Further examination of the words revealed that mistakes made by the two different treatment groups differed. Test done on a room with Naava had a total mistake count of 12, whereas the same number for a room without a Naava was 28. The difference was statistically significant (n = 12, p = 0.03). There was no statistically significant difference in the amount of mistakes made between the first and second day (n = 12, p = 0.81).

Number of mistakes

Group	Total	Average	Median	SD
Total	40	1.67	1.5	1.4
Day 1	21	1.75	1	1.54
Day 2	19	1.58	2	1.38
No Naava	28	2.33	2	1.23
Naava	12	1	0.5	1.35

VAS questionnaire

The average **mood** before the test was 6.2 (SD = 1.50, n =12) and after test 6.8 (SD = 1.19): test subjects reported statistically significantly higher mood after the test was done (p=0.008). After the test, mood reported in the room without Naava was an average of 6.49 (SD = 0.86, n = 12) and for the room with Naava an average of 7.11 (SD = 1.42, n = 12). This difference between the rooms was not statistically significant (p = 0.08).

The average **environmental comfort** for the lobby hall where participants first filled in the questionnaires was 5.7 (SD = 1.48, n = 24); 6 for the test room without Naava (SD = 1.32, n =12); and 6.83 for the test room with Naava (SD = 1.4, n = 12). The environment in both classrooms was rated more comfortable compared to the lobby where

they first filled the questionnaire (p = 0.007). From the two classrooms, the one with Naava was rated more comfortable and the difference was statistically significant (p = 0.04).

The average **anxiety** before the test was 2.78 (SD = 2.31, n = 12) and 1.71 (SD = 1.76, n = 12) after the test: test subjects reported statistically significantly lower anxiety after the test was done (p = 0.003).

The average **fear** before the test was 1 (SD = 1.61, n = 12) and 0.45 after the test (SD = 1.02, n = 12): test subjects reported statistically significantly lower fear after the test was done (p = 0.001). After the test, fear reported in a room without Naava was an average of 0.58 (SD = 1.18, n = 12), and in a room with Naava an average of 0.38 (SD = 0.87, n = 12). This difference between the two rooms was not statistically significant (p = 0.06).

Temperature

Skin temperature measured from the tip of the nose was on average 29.4℃ before the experiment and 30.6℃ after the experiment. This increase in body temperature was statistically significant ($p<0.05$) and more pronounced on day one. There were no significant differences between Naava and without Naava rooms nor different days.

Heart rate variability

HRV significantly varied between subjects ($p <0.05$, 1-way ANOVA). This variation was so large that it masked all other possible changes. For example, in 2-way ANOVA both before-after and Naava-without Naava conditions showed significant interaction with subject (both $p <0.05$, respectively), but did not show significant differences when compared individually against the HRV. Similarly, the 2nd day measurements showed larger values than the 1st day measurements, but, again, this was not statistically significant.

Hormonal analysis

Cortisol and oxytocin hormones were analyzed from saliva. Additionally oxytocin was analyzed from plasma, but due to difficulties in sampling, N was less than 50 % of the original and the results are not comparable thus dropping them out of the comparison.

Hormonal level change in measurements before and after stress test show a clear change in the presence of Naava: oxytocin levels rise (Figure 2) and cortisol levels drop (Figure 1) near the greenwall. Although the average change in the hormonal levels correspond to nearly 10 % of the reported human average values (0.1-1 µg/dL for cortisol and 5–100 pg/mL for oxytocin), the finding is not significant ($p = 0.2$ for cortisol and $p = 0.15$ for oxytocin).

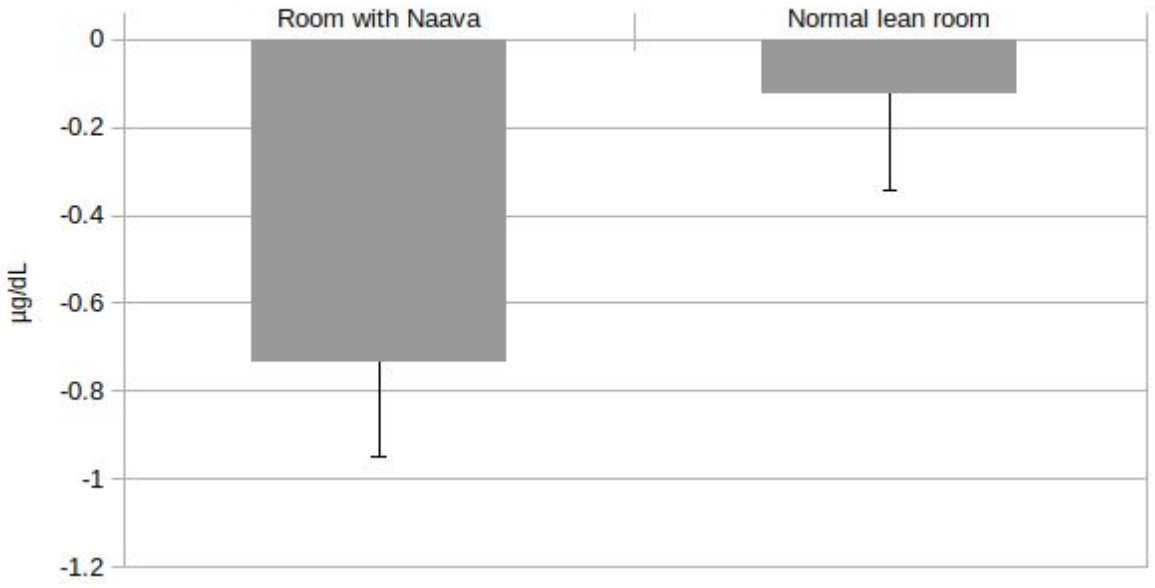

Figure 1. Change in saliva cortisol level in relation to stress test

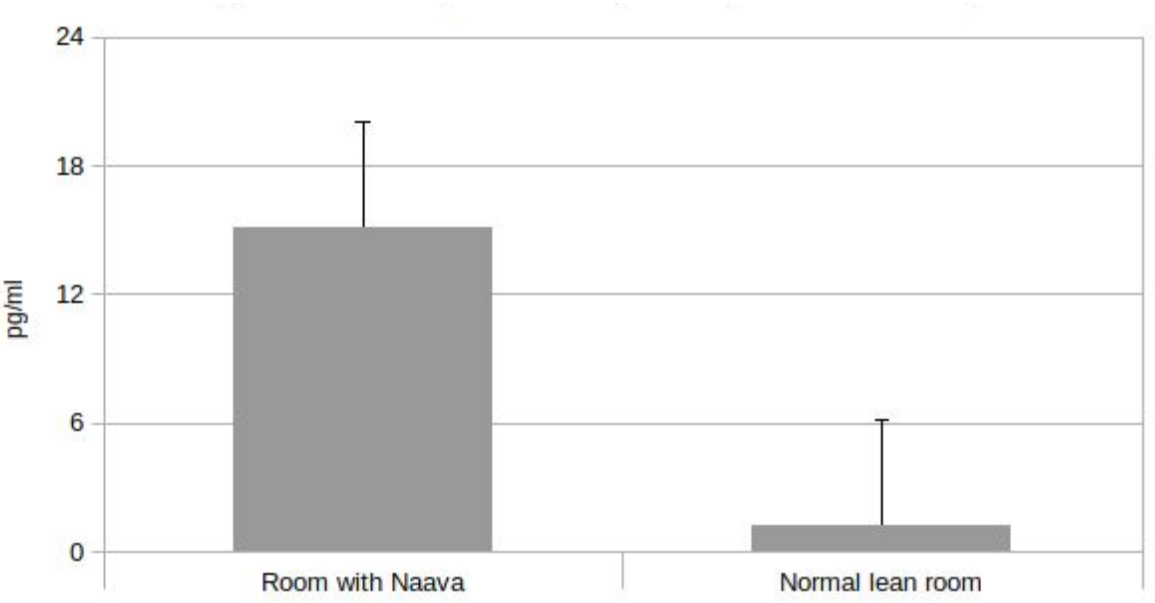

Figure 2. Change in saliva oxytocin level in relation to stress test

Conclusions and discussion

First, it is important to note that the study group consisted of only 12 participants, whom which 11 were female. No comprehensive results can be generalized to public based on this study. The following conclusions give directions to possible explanations of the results gotten from this study, but their main function is to give direction to the possible future studies with larger test groups.

Plants have been known to have a bigger impact on females (Shibata & Suzuki 2002). As 11 of the 12 test subjects were females, it is possible that these results are more pronounced compared to general public. On the other hand, for the purposes of this study, almost an all-female test group might have been beneficial as the effect is more pronounced and might have an counter effect on the small sample size.

Word association test

Previous studies using word association test as a tool have not reported significant differences among gender or age (Ruff et al. 1996). The amount of words invented were strikingly similar with very little variation. This indicates that the used test was reliable, and the randomly assigned words had little to no effect on the results. This tool would therefore be useful in future studies as it is or with modifications.

The difference of only 4 words between the treatment groups was not significant: this means **Naava had no impact on the amount of words a test subject could come up with** within the given time. This indicates, that the test included enough opportunities for each subject to keep making up words at a similar pace, and a difference/variation would have been more likely seen, if the words would have been more difficult or if there had been less choices, forcing the test subjects to think harder for the possible associations. This might make it possible to find effects on e.g. creativity.

However, when the tests were further investigated, differences emerged. It was apparent that the amount of mistakes made between treatment groups differed, and the result was statistically significant.

When the test was done in a room with Naava, subjects made 42.9 % less mistakes. On the contrary to improving on the actual amount of words during the second test day, there was no significant difference on the amount of mistakes made between the days. This indicates, that the contributing factor on the amount of mistakes made might be the Naava greenwall.

There are two possible explanations to the higher amount of mistakes done in the room without Naava greenwall. The results can be explained by either biophilia and Attention Restoration Theory, or the effect of air quality on the test subjects: most likely the effect is a combination of them all.

Biophilia explains, that during our evolutionary history, our brains have adapted to seek natural elements from our surroundings. Plants have been a sign of food, water, and shelter, and therefore indicate a safe environment. According to the Attention Restoration Theory, this allows our minds to rest when we see nature around us: it has an unconscious effect on our attention, allowing our mind to concentrate on the task instead of being alert of the environment. Dornic (1977) states that: “Attentional demands required to comprehend or produce a language, as well as allocation of physical and mental resources to performance of language-related tasks may affect the pool of cognitive resources that can be used during problem solving in a language”. The lower amount of mistakes in the tests done in a room with Naava greenwall could be the result of our minds being able to restore attention better during the breathing exercise, and therefore concentrate better on the details of the task.

VAS questionnaire

As expected, the test subjects reported less fear and anxiety on the second test day compared to the first. They also reported less fear and anxiety as well as better mood after the test was done. There was no significant differences between the first and second experiment days for the before and after results. The classrooms with Naavas were rated as more comfortable. These results can be explained by biophilia and possible the quality of the air.

Temperature

Noninvasive and fast temperature sampling with the thermal imaging camera was not as reliable as traditional ear measurement. Targeting the tip of the nose was difficult and deviations between replicates were so big that subtle differences in actual body temperature were below detection limit

Heart rate variability

HRV varies between individuals very much. Also the choice of prioritizing hormonal analysis, including taking blood samples, over HRV breathing excercises must have influenced the results as some people are nervous of needles. In future experiments the breathing exercise should be temporally better controlled and include more participants.

Hormonal analyses

Despite the fact that no statistically significant results were able to be produced for the hormonal analyses (likely due to the small sample size and large variation), there was a uniform trend: oxytocin levels rose and cortisol levels dropped in the Naava rooms. This pattern is interesting and should be studied in further detail, as it could give novel information and have scientific value. Using plasma to measure oxytocin has not proven to be very effective in this case, as saliva samples are easier to collect, cause less stress and therefore an no significant additional variation to hormonal levels of subjects, and were easier and more effective to analyse. Saliva samples are also more likely to show the short-term changes in hormonal levels, which is what a study in this case would prefer to measure. Therefore I suggest, collecting only saliva samples in future studies.

In conclusion

Although physiological results were not statistically significant, they all pointed towards same direction: HRV increased, levels of cortisol, stress hormone, were lowered and levels of oxytocin, prosocial hormone, were increased. Taken together with the less mistakes and more environmental comfort results, it seems plausible that Naava does

facilitates concentration and focusing, because relieved task related stress.

Due to the small sample size, in the current study, the above results should be verified with further experiments.

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