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Author(s)	Kenneth Y T Lim and Xinyue Wu

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An investigation on the effects of different types of odours on stress level of high school students when studying

Kenneth Y T Lim[a]*, Xinyue Wu[b]

[a]*National Institute of Education, 1 Nanyang Walk, Singapore 637616, Singapore*
[b]*Independent*

Abstract

In view of the mental health issues among adolescents in Singapore, aromatherapy is proposed to mitigate their stress level when studying. An experiment was conducted both in the classroom and home setting, to test the effectiveness of the give odours, lavender, rosemary, ylang-ylang, lemon and bergamot on reducing stress level, using the no odour scenario as control. Objective data (SpO2, heart rate and stress score) is collected using the HUAWEI Band 6 smartwatch. Subjective data was self-reported by the participants through Google forms, rating their emotional health on a 10-point scale and elaborating in prose. It was found that the anti-anxiety effects of the stimulants (lemon, bergamot, rosemary) were much larger than that of the sedatives (lavender, ylang-ylang). In particular, lemon showed the best objective anxiolytic effect, while bergamot was the best in terms of self-perceived effect. Rosemary relieved stress through raising productivity, but some effects of overworking were observed. On the other hand, ylang-ylang showed inconsistent effects, while lavender was not suitable to relieve stress when studying.

Keywords: odours ; essential oils ; stress level

* Corresponding author. Tel.: +65-67903409
E-mail address: kenneth.lim@nie.edu.sg

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1. Introduction

Mental health has become a prevalent issue in Singaporean adolescents, with one in three youth having mental health symptoms such as anxiety [1]. Meanwhile, in 2021, Singapore's Minister for Education emphasised that the mental well-being of students would always be a priority [2]. Zooming in, the greatest source of stress among Singaporean adolescent students is study commitments [3]. Hence, it is of utmost urgency to find a way to relieve the stress level of adolescent students when performing studying tasks. Aromatherapy is widely employed to achieve the effects of relaxation, anxiety reduction, and enhanced energy [4]. As such, it could be a possible remedy to the declining mental health of Singaporean adolescents. However, the efficacy data for aromatherapy is scant, and the potential mechanisms of action involved in aromatherapy are controversial [5]. This paper reports an independent research project conceptualized, designed and enacted by a high school student in Singapore, under the mentorship of the lead author. The study aimed to bridge the gap in existing literature through collecting datasets and, based on that, propose the effects of different types of odours on stress levels of adolescent students when studying. This study was conducted with several underlying assumptions: sensors and smartwatches collect accurate data; participants of research provide reliable self-reported data; change in stress levels between different datasets is due to the change in type of odour. To ensure the reliability of the experiment, other environmental factors were kept generally constant in a comfortable range. The main constraint in the experiment was the number of smartwatches, which was only two sets due to their high costs. Additionally, the availability of the participants posed constraints on the experiment duration and number of experiment sets. The remainder of this paper is organized as follows: section 2 is the review of Literature, section 3 describes Methodology, section 4 shares Results, section 5 represents the Discussion, and section 6 draws Concluding remarks.

2. Literature review

Essential oils are extracted and highly refined fragrant substances produced by some plants [6]. The practice of aromatherapy utilises essential oils to treat various mood disorders [7], and to alleviate symptoms of stress-induced anxiety [8]. The history of aromatherapy dates back to as early as the 1920s [9], and has been empirically tested to be effective against cognitive issues, depression, insomnia and stress-related problems [10]. The basis of aromatherapy is the systemic effect theory, better known as “lock and key”, which contends that essential oils have similar functions to a drug or enzyme, such that particular odours should have very specific effects [11]. When the essential oil is inhaled, its molecules are absorbed by the nostrils, contacting the olfactory nerves that are directly connected to the Central Nervous System. The stimulus is then taken to the Limbic System that is responsible for human feelings, memory, impulses and emotions [12]. In particular, certain odours may induce positive moods, enhancing both physical and psychological well-being. For example, the essential oils of the Lavandula [13] and Citrus [14] species have anxiolytic, sedative, and antidepressant effects.

3. Methodology

The experiment will be conducted in the classroom and home setting, the two most common places for studying. For the classroom, an air-conditioned room in a high school in Singapore was chosen, with fans as ventilation. The home environment will be the study room of each participant in their respective houses. The experiment involves putting a commercial portable aroma diffuser in the centre of the room, with a few drops of essential oils, spreading the odour out across the room as evenly as possible. The participants are seated at separate corners of the classroom and at their studying desks at home, doing mathematics questions. The experiment lasts for a duration of two hours each day, for 12 days in the afternoon (12pm - 2pm) in November 2022. The first six days are conducted in school, with a different type of odour each day (in the sequence of: no odour, lavender, rosemary, ylang-ylang, lemon, bergamot), and the last six days repeat the same process at home. The no odour situation is included for control purposes. To ensure a fair experimental setting, the microclimate environmental factors are tracked by Arduino sensors and controlled to be within a comfortable range for conducive studying, minimising their effects on the experiment results. Firstly, the Grove - Sunlight Sensor detects ultraviolet (UV)-light and visible light. UV-light is kept within 0-2 in the low range of the Ultraviolet Index [15], while visible light is between 300 to 500 lux [16], the recommended

level for classrooms. Secondly, the Grove - Carbon Dioxide & Temperature & Humidity Sensor (SCD30) tracks the carbon dioxide concentration to be between a healthy range of 400 to 800 ppm [17], temperature at 22 degree Celsius optimal for learning [18], and accordingly, relative humidity in the thermal comfort range of 75% to 85% [19]. Thirdly, the Grove - Barometer Sensor (BME280) reports that air pressure is between 100000 and 120000 Pa, well within human comfort range [20], whereas the Gravity:I2C BME680 Environmental Sensor outputs the Indoor Air Quality Index to be below 50, in the healthy range [21]. Finally, the Grove - Analog Microphone certifies that the noise level is ideal for studying, being constantly below 40 decibels [22]. The participants of this experiment were selected to be one male and one female junior college student (17-18 years old). This was to ensure accountability of the results for both genders, as women have a more acute sense of smell than men as assessed by the standardised tests of odour identification and detection [23]. Throughout the experiment, the participants wore a HUAWEI Band 6 smartwatch [24], which measured:

- the oxygen saturation in blood: SpO_2 (in %);
- heart rate (in beats per minute, bpm); and
- stress score (out of 100).

3.1. SpO_2

SpO_2 refers to the oxygen saturation in blood, which is defined as the amount of oxygen-carrying hemoglobin in the blood relative to its capacity [24]. The normal SpO_2 level of healthy people is 95 to 100% [25]. Values lower than the normal range will cause changes in cognitive functions such as attention, memory, and decision-making ability [26]. For SpO_2 in the normal range, a lower SpO_2 will correspond to a lower stress level [27].

3.2. Heart rate

The smartwatch utilised the HUAWEI TruSeen™ 4.0 technology for heart rate monitoring, ensuring accurate results through LED lens and AI algorithm [28]. The resting heart rate for an average adolescent (17-18 years old) is 60 to 100 bpm [29]. Exposing a person to a stressor will trigger his autonomic nervous system (ANS), suppressing the parasympathetic nervous system and activating the sympathetic nervous system [30]. As a result, the “fight-or-flight” reaction causes the epinephrine and norepinephrine hormones to be secreted into the bloodstream, leading to an increase in heart rate [31].

3.3. Stress score

The smartwatch utilised the HUAWEI TruRelax™ 4.0 technology to measure heart rate variability, which reflects the ANS that controls stress level [24]. To ensure accuracy of results, a calibration was performed before data collection, which included a survey and a heart rate check. The stress models for stress level evaluation are certified by the Institute of Psychology, Chinese Academy of Sciences. The ranges for stress score are: 1 to 29 for low, 30 to 59 for normal, 60 to 79 for medium and 80 to 99 for high.

After the experiment, the participants were asked to self-report two questions through Google forms. The first asked them to rate their emotional health based on the odour against a 10-point scale, while the other question asked them to elaborate their respective responses in prose. The quantitative and qualitative subjective responses, and objective data from the smartwatch, ensured reliability of the assessment of participants’ mental well-being. Existing studies mostly examines stress levels in rats with methods like tail suspension test, and mood studies on human usually only relies on self-reported mood or results from the test participants do. Our methodology covers the area where objective, physiological human data are measured.

4. Results

Tables 1 and 2 show the SpO_2 levels of the participants in the classroom and at home, respectively.

Table 1. SpO_2 level of the participants in the classroom

	Male	Female
No odour	98%	98%
Lavender	100%	97%
Rosemary	95%	100%
Ylang-ylang	99%	95%
Lemon	100%	98%
Bergamot	98%	96%

Table 2. SpO_2 level of the participants at home

	Male	Female
No odour	100%	98%
Lavender	98%	98%
Rosemary	98%	99%
Ylang-ylang	100%	97%
Lemon	100%	96%
Bergamot	96%	96%

Tables 3 and 4 show the heart rate of the participants in the classroom and at home, respectively.

Table 3. Heart rate of the participants in the classroom

	Male	Female
No odour	119bpm	104bpm
Lavender	96bpm	82bpm
Rosemary	88bpm	90bpm
Ylang-ylang	104bpm	85bpm
Lemon	104bpm	94bpm
Bergamot	88bpm	86bpm

Table 4. Heart rate of the participants at home

	Male	Female
No odour	116bpm	106bpm
Lavender	91bpm	86bpm
Rosemary	81bpm	83bpm
Ylang-ylang	75bpm	99bpm
Lemon	87bpm	85bpm
Bergamot	72bpm	78bpm

5. Discussion

Participants are generally more stressed in the classroom with the stress score across all six scenarios averaging at male: 26.3, female: 26.3 than at home with male: 19.3, female: 22.5. Moreover, for both participants, their stress scores at home are in the low range below 30. However, this does not correspond to the self-reported emotional health level, where the male average is 8.2 both in classroom and at home, and female average is higher in school at 7.3 compared to 6.5 at home. From the qualitative responses, the inaccuracies in self-perception of one's emotional health can be due to a lower productivity at home. When filling in the Google form, the participants have finished their studying

session. Once they realised they had not done enough work, it may have induced stress on themselves, affecting their self-perception at that point in time.

Table 5. Changes in stress score of the participants

	Classroom (Male)	Home (Male)	Average (Male)	Classroom (Female)	Home (Female)	Average (Female)	Average (Male & Female)
Lavender	+6	-8	-1	-7	-8	-7.5	-4.25
Rosemary	-17	-6	-11.5	-12	-6	-9	-10.25
Ylang-ylang	-4	-12	-8	-19	0	-9.5	-8.75
Lemon	-14	-8	-11	-11	-13	-12	-11.5
Bergamot	-5	-12	-8.5	-15	-12	-13.5	-11

It is evident that the participants are generally more stressed under the no odour situation, with stress scores 27 to 37, around the low to normal range. Hence, the presence of odours of essential oils generally lower the stress levels of the participants. This is further supported by the no odour situation having the highest heart rate of 104 to 119 bpm. However, an exception is the stress score of the male participant at 38 under the lavender odour in school, exceeding the control of 32. A similar conclusion can be drawn from the corresponding SpO_2 level of 100%, being higher than the control of 98%. A reason for this could be the male participant feeling dizzy from the lavender odour, as mentioned in his qualitative response. His heart rate is also generally faster under the lavender odour in both environments. The effects of lavender essential oil differ according to the intensity and duration of exposure [33]. In the case of the male participant, long exposure to the lavender odour caused him to be more stressed.

The odours most effective for reducing stress is rosemary and lemon for the male participant, and on the other hand, lemon and bergamot for the female participant. Overall, lemon and bergamot can decrease stress levels most effectively, averaging at 11.5 and 11 respectively. The similarity in results is possibly due to bergamot being a hybrid of bitter orange and lemon [34], hence its properties largely overlap with lemon. The participants' qualitative responses also support this conclusion, remarking that the bergamot odour resembles that of lemon's. However, they also commented that lemon smells more acidic, making them slightly uncomfortable. This is reflected in their self-perceived emotional health, where bergamot is about one point higher than lemon in all scenarios. The highest self-reported emotional health for the bergamot odour can also be attributed to the low SpO_2 level of 96% in all scenarios with the exception of 98% when the male participant is in the classroom, as well as the the lowest heart rate in all scenarios except when the female participant is in the classroom, where it is still rather low at 86 bpm.

Lavender has the least effect for both participants, reducing the stress level and SpO_2 level only marginally. This is likely due to it decreasing memory and attention in humans [35], showing different results from how it facilitates memory formation in rats [36], thus inducing more anxiety as learning is made more difficult. Unlike [37], lavender odour decreases heart rate to some extent, lowering by 20 bpm on average for both participants, indicating its anxiolytic potential [38]. Its relaxant properties [39] might have led to drowsiness, which is mentioned in the qualitative responses and seen in [40]. Therefore, the self-reported emotional health has decreased slightly on average compared to controls. However, the male participant acknowledges the effect of lavender odour to relieve his headache when studying, supporting [4]. Moreover, both participants respond that the lavender odour gives them a better mood, yielding similar results as [35]. Hence, lavender's anxiolytic potential [38] may be realised when resting, but not for activities in which productivity is concerned.

Rosemary has shown a moderate effect on relieving the stress of both participants, and in particular, has been the most effective odour for the male participant. His decrease in stress score is especially large in the classroom setting, with similar conclusions drawn from his lowest heart rate at 88 bpm and SpO_2 at 95%, indicating that he feels relieved under the rosemary odour. The qualitative responses indicate a large increment in productivity in doing math questions, concurring with [40], making them highly satisfied with a good mood, similar to the participants in [35]. Notably, rosemary has seen a 1-point increment in self-reported emotional health in all cases except for the female participant at home, where she explains that she has completed too much work with the increased productivity that she feels worn

out. Such an evidence would be her high SpO_2 levels under the rosemary odour, being at 100% in the classroom and 99% at home, likely due to the increased alertness caused by rosemary odour [40]. Thus, rosemary is effective in relieving study-related stress by increasing productivity, but there is a risk of overworking.

Interestingly, the effect of ylang-ylang varies very largely under different settings and for different participants. For the male participant, his stress score decreased marginally under the classroom setting, but the decrement is large at home. This corresponds to his heart rate data, where the decrease is 31 bpm at home, but only 15 bpm in the classroom. On the other hand, his SpO_2 level is high at 99% and 100% in the classroom and at home respectively, implying that the ylang-ylang odour caused him to increase alertness as claimed by [41]. His self-reported emotional health is also rather high, as he mentions in his Google form response that he likes the sweet and pleasant ylang-ylang odour which makes him feel like in nature, similar to what [42] describes as a revitalising sensation.

Unlike the male participant, the female participant has a huge decrease in her stress level in the classroom, while there is no change to her stress level at home. This corresponds to her heart rate data, where the decrease is 19 bpm in the classroom, but only 7 bpm at home, having the highest heart rate of all scented scenarios. Summarising the heart rate data of both male and female participants under the ylang-ylang odour, it can be concluded that the claim in [41] about ylang-ylang decreasing heart rate seems to be true, but the exact decrement fluctuates. Another large difference lies in the SpO_2 levels, where the female participant is at low values of 95% and 97% in the classroom and at home respectively. This is possibly due to the female participant reporting drowsiness and sleepiness similar to the participants in [11], as opposed to those who feel more alert in [41]. The difference in effect may be due to how the participants perceive the odour differently, where the female participant dislikes the odour, seeing it as artificial. This can also be seen in her self-reported emotional health, being 1 less than controls under all situations with the ylang-ylang odour. Therefore, it can be concluded that the ylang-ylang odour has some extent of anxiolytic effects, even though it is highly inconsistent due to possible factors such as how the odour is perceived.

6. Conclusion

In conclusion, the anti-anxiety effects of the stimulants (lemon, bergamot, rosemary) are much larger than that of the sedatives (lavender, ylang-ylang). Being similar in their properties, bergamot and lemon can consistently lower the stress levels of both participants. Rosemary has also displayed reliable de-stressing effects through enhancing productivity, even though there is a possible side effect of wearing out due to overworking. Ylang-ylang has some observable calming effects, but it is highly inconsistent depending on the participants' liking of the odour. As for lavender, the anti-anxiety effects are low, as it lowers productivity and induces more stress on the participants. An advice would be to apply it during rest sessions, possibly improving the quality of relaxation and thus, enhancing studying performance [43]. The limited number of subjects is the main limitation to a possible generalization of results. In future , this work may be developed with a study involving a large number of participants, so that the results can be generalissd to a larger population. Variables other than stress levels might also be measured, such as productivity. Alternatively, stress levels of students performing other tasks or activities could be measured, such as when they are sleeping or exercising.

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