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To Blend or Not to Blend? Anxiety Buffering Effects of Essential Oil Aromas

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Abstract

Essential oils of pure lavender and lavender blends have been employed as potential anxiolytic aromas in aromatherapy, but a direct comparison of their effectiveness is lacking. The current study investigated the effects of aroma on induced anxiety in non-clinical adults, comparing pure lavender, a commercially available blend and a no aroma control. An experimental, quantitative, mixed factorial design with an opportunity sample of 60 participants was employed. Participants were randomly allocated to three equal groups, one tested in a room infused with lavender aroma, the second with the doTerra Peace® blend, and the third free from any aroma. Participants' state anxiety scores were measured before and after a novel video-based anxiety induction procedure. Data analysis revealed that the anxiety induction was successful and that both aromas delivered small to medium-sized buffering effects compared to no aroma. The findings add to a small body of research in an area where the practice is global yet has limited scientific evaluation. Future studies utilising brain imaging and blood serum analysis to investigate the anxiolytic mechanism of aromas would be beneficial to further our understanding.

Keywords

Aromatherapy, Lavender, Essential Oil, Blend, Anxiety Buffering

1. Introduction

Globally, record numbers of adults are seeking help for their anxiety [1], and in response to the COVID-19 pandemic, anxiety has spiked across the population of entire countries [2] suggesting it may become an epidemic in its own right. Treatments for anxiety are unsurprisingly a focus of psychological research to

deliver improved quality of life for sufferers and economic advantages within countries. Many pharmacological, psychological and combined treatments are currently employed, but the benefits are especially salient to investigate when the treatment can be administered outside the clinical setting by the patient or another non-healthcare professional. Consequently, there has been a shift in the focus towards alternative medicinal routes and their efficacy. Aromatherapy is an expanding area of alternative medicine, progressively used alongside conventional medicine [3]. The therapeutic use of essential oils extracted from plants has a long history with ancient Greeks, Indians, and Egyptians using aromatherapy for healing purposes [4]. Essential oils were first commercially produced in the early 19th century during the industrial revolution [5] and by the 1960s, the oils were retailed for modern aromatherapy in Britain as the prevalence of holistic treatments spread across Europe [6]. Since this point, the popularity of modern alternative medicine progressed around the globe, capturing the interest of psychology researchers who began trials to determine the efficacy of the claims made.

Early studies identified that essential oils seem to influence mood, with rosemary and lavender oils enhancing positive mood states [7]. Burnett, Solterbeck and Strapp [8] reported distinct effects upon self-reported aspects of mood between individual oils. Such individualised effects have also been mirrored for objective measurements. Campenni, Crawley and Meier [9] showed that heart rate decreased in response to a relaxing aroma, whereas stimulating aromas increased heart rate. The findings of Burnett *et al.* and Campenni *et al.* demonstrate how the particular oil chosen for a treatment session may influence the outcome. Subsequently, review papers have stressed the positive benefits of aromatherapy on anxiety levels [10] [11] [12] [13]. The reviews have consolidated the work of many smaller experimental studies and identified oils that have produced anxiolytic benefits, such as sweet orange, basil, lavender, and sweet marjoram [14]. A contemporary review focussing on the benefits of lavender essential oil reported effects that span from post-surgical pain relief to mitigating anxiety [15]. Further research demonstrates that lavender oil consistently aids in anxiety buffering on both self-report [16] and physiological measures [17].

Lehrner, Marwinski, Lehr, Johren and Deecke [18] compared patients' state anxiety levels whilst waiting for treatment in a dentist's office, with 200 participants inhaling either aroma of lavender, sweet orange or no essential oil. They found that participants inhaling lavender reported lower levels of state anxiety. Another subsequent study, also carried out in a dentist's office, compared lavender to no essential oil and found converging results in terms of state anxiety reported by those exposed to lavender [19]. From a more clinical perspective, Braden, Reichow and Halm [20] reported lavender essential oil's anxiety-reducing potential in preoperative patients compared to a control group, who received treatment as usual. McCaffrey, Thomas and Kinzelman [21] found that inhaling lavender essential oil aroma reduced physiological markers of anxiety including

pulse rate in nursing students before entering the exam period. Similar studies have demonstrated that lavender essential oil aided in the promotion of immunoglobulin A (s-IgA) secretion [22], a reduction in chromogranin A (CgA) secretion [23] and in blood pressure [24]. Biologists have previously identified that an increase in CgA secretion, blood pressure and depletion in s-IgA secretion are physiological indicators of stress in humans. Regarding self-report scales, research has also shown lavender aroma to produce anxiety buffering on the Depression, Anxiety and Stress scale [25] and on the State Anxiety Inventory (18, 19). A systematic review of 37 randomised controlled trials concluded that lavender inhalation reduced anxiety at a significant level on any validated anxiety scale [26], providing compelling evidence for the psychological and physical influence of inhaling lavender aroma.

The development of essential oil blends allows for the potential benefits of individual oils to be coupled together, potentially producing a whole that may be greater than the sum of its parts. In practice, aromatherapists rarely use single essential oils, opting for a blend to integrate the properties for treatment [27]. Numerous created and retailed blends include lavender oil and tend to attribute the claims reported for pure lavender to the blend. Investigation of the blends' effectiveness in fulfilling these claims is important. Jo [28] investigated the stress-reducing efficacy of an essential oil blend of Lavender, Geranium and Marjoram in a respective 5:3:2 ratio with 48 nurses, reporting buffered stress increase pre- to post-treatment when compared to a control group. A recent study supported these findings with a 7:3 blend of lavender and rose, detailing lower state anxiety scores in nursing students after inhaling the blend against a control group [29]. Outside of the nursing environment, healthy but headache prone participants described fewer experiences of state anxiousness following inhaling a blend that included lavender, combined with chamomile in a 6:4 ratio [30]. Lavender essential oil blends have also been tested in conventional clinical care. High-risk post-partum women produced a lower anxiety scores when inhaling a 1:3 blend of rose and lavender in eight sessions over four weeks when set against a control [31]. Similarly, researchers have demonstrated anxiety mitigation for surgery patients. Preoperative hysterectomy patients experienced lower pulse rates following inhalation of a blend of lavender, ylang ylang and bergamot in a 5:3:2 ratio [32]. Additionally, percutaneous coronary intervention patients who received a 12:4:1 respective blend of lavender, roman chamomile and neroli self-reported greater anxiety buffering pre- to post-surgery against a control [33].

Considering how inhalation of the aromas of pure oils and blends may be advantageous for taking control of one's health and wellbeing in those who do not require clinical treatment, there is no surprise that this retail market is ever-growing. The appeal of a natural, holistic treatment that can be administered in many ways, from diffusion to massages, drives sales [34]. Companies sell manufactured essential oils globally, yet the largest market resides throughout Europe [35]. As of 2020, the essential oil market was valued at 18.6 billion USD with a projected Compound Annual Growth Rate of 7.4% for revenue from 2021 to

2028 (Grand View Research, 2021). One dominant brand in this market is doTERRA, an essential oil retailer selling several pure oils and blends and advertising their brand as superior based upon their sustainable oil sourcing and purity of the oils [36]. They trade with at least 34 countries in the most extensive market region, Europe, and throughout Asia, Oceania, and America. One blend they developed consists of Lavender, Vetiver, Ylang Ylang, Clary Sage, Spearmint, Marjoram, Labdanum and Frankincense in an unspecified ratio, labelling this blend *Peace*® [37]. doTERRA [38] claim that this blend will reduce anxiety in preparation for a stressful event and promote a calming environment designed to assist in falling asleep, among other suggestions of a similar nature. They propose that their claims come from a heavily investigative basis, indicating that they conduct research before marketing each oil or blend [39]; however, no such evidence carried out by themselves, or any other researcher is publicly available for the *Peace*® blend. Thus, an investigation into these claims is salient to validate the proposal put forward by doTERRA.

On the whole, research suggests that lavender and blends that include lavender do have positive benefits for anxiety management or mitigation across several validated anxiety scales and physiological responses. That said, the literature testing the efficacy of lavender essential oil rarely appointed a pre- to post- methodology. Hence, researchers cannot concretely suggest anxiety buffering due to the inhalation of lavender. As there was no measure from before to after, the authors cannot definitively claim that anxiety was induced or mitigated as it is not certain that participants experienced it. Furthermore, the research into essential oil blends has hitherto not experimentally induced anxiety; instead, their methodology focused on a naturally stressful event or environment. It is possible that factors independent from the inhaled essential oil aroma may act as moderators for the anxiety experienced, potentially impacting the results. To address these limitations, the current study investigated anxiety levels using an experimentally induced anxiety protocol and incorporated anxiety levels measured pre and post. Despite the use of physiological measures of stress throughout some previous studies for both lavender oil and lavender blends, this study focused on how participants *felt* in response to the presence of the essential oil aroma and anxiety induction. Reporting results from the participants' perspective remains aligned with promoting personal wellbeing, a key goal of aromatherapy [40], and ensures the most valuable findings are highlighted. Thus, a self-report measure is more appropriate. Accordingly, the current study employed a quantitative validated state anxiety measure, given that state anxiety has been consistently utilised throughout aroma and essential oil research [19] [29], and is sensitive to change [41].

Here we compared participants under three conditions: no aroma, lavender aroma, and *Peace*® aroma. Comparing the efficacy of the two aromas with similar claims in anxiety buffering is of significant interest for understanding the potential value of blends. The inclusion of a control group will ensure the stress induction alone is valid and will allow for comparison between the efficacy of aroma groups and no aroma. This experimental study is the first to our know-

ledge to investigate the claims of doTERRA's essential oil blend *Peace*®, and thus, the hypotheses were based on the available research: [1] The video based induction will increase anxiety levels across participants' pre to post scores. [2] Lavender will mitigate the anxiety inducing effect compared to a control. [3] *Peace*® blend will mitigate the video effect compared to a control, but we cannot predict whether this may be more effective than lavender alone.

2. Materials and Methods

2.1. Design

An experimental, quantitative approach was coupled with a mixed factorial design to investigate the effects of aroma on induced anxiety. The independent groups factor was the aroma condition with three levels, no aroma, lavender aroma and the doTERRA *Peace*® blend aroma. The repeated measures factor was the timepoint at which the self-report anxiety scale was completed and had two levels, pre and post anxiety induction. The dependent variable was anxiety score, measured on the State-Trait Anxiety Inventory (S-form) [42] with higher scores indicating higher anxiety levels.

2.2. Participants

An a priori power analysis conducted using G power [43] [44], recommended a sample of 60 participants, based on a power of 0.80, alpha level of 0.05 and large effect size ($F^2 = 0.42$) derived from a meta-analysis of aromatherapy [45]. Participants were required to be 18+ years of age and not possess specific sensitivity to issues of police brutality due to the nature of the anxiety-inducing video. All participants self-reported no lung sensitivity such as severe asthma or COPD, and none had a diagnosed anxiety disorder. The participants were recruited via posters on the university campus and social media advertising an eye witness memory study. No mention was made of aromas or essential oils in an attempt to remove any expectancy effects. The participants were randomly, evenly assigned across the three conditions with 20 in the *Peace*® condition (Male = 4, Female = 16; M age = 38.60 SD = 23.63); a further 20 in the lavender condition (Male = 8, Female = 12; M age = 35.30 SD = 19.15); and the final 20 in the control condition (Male = 4, Female = 16; M age = 33.85, SD = 18.96).

2.3. Materials

2.3.1. Aroma Materials

The doTERRA essential oil blend *Peace*® and Tisserand® pure lavender essential oil were employed in this study.

2.3.2. GC-MS Analysis

Gas chromatography-mass spectrometry (GC-MS) analysis was performed on the Tisserand® lavender and the doTerra Peace® essential oils using a Thermo Scientific Trace 1300 GC coupled to a ISQ QD single quadrupole mass spectrometer equipped with a AI1310 liquid autosampler (Thermo Fisher Scientific,

Hemel Hempsted, UK). Each sample was diluted 1000-fold in methanol and 1 µL was injected into the GC. Chromatographic separation was achieved using a TG5-MS (30 m × 0.25 mm, 0.25 µm film thickness) column (Thermo Fisher Scientific, Hemel Hempsted, UK) using the parameters in Table 1. Data analysis was performed using Xcalibur chromatography data system software (Thermo Fisher Scientific, Hemel Hempsted, UK)

The chromatogram shown in Figure 1(a) is consistent with doTerra Peace®

Table 1. GC-MS operating conditions.

Parameter	Setting
Inlet temperature (˚C)	280
Split ratio	10
Carrier gas	Helium
Carrier gas flow rate (mL/min)	1.0
Oven temperature (˚C)	50˚C hold for 1 min then increase at 5˚C/min to 250˚C
MS transfer line temperature (˚C)	280
Ion source temperature (˚C)	280
Scan type	Full Scan
Scan range	40-650

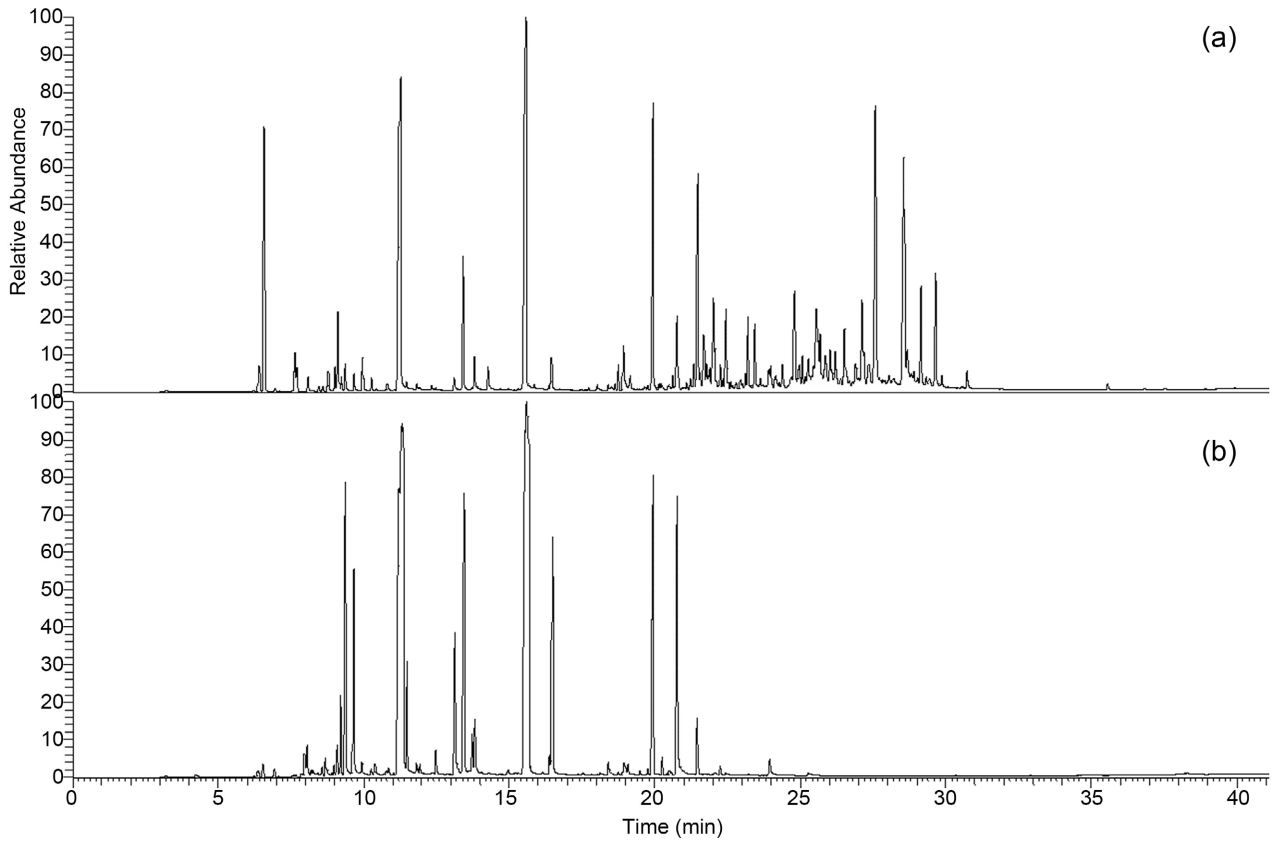

Figure 1. Full Scan chromatogram of (a) DoTerra Peace® and (b) Tisserand® lavender essential oils.

essential oil being a blend due to the presence of additional peaks not observed in the chromatogram of the Tisserand® lavender essential oil shown in **Figure 1(b)**. The peaks were tentatively identified based on the MS reference NIST 2014 library and the compounds compared against previously published literature. [46]-[101] (**Table 2**). Based on the compounds present within the doTerra sample it would indicate that the blend contains vetiver root, lavender, marjoram, Ylang Ylang, frankincense and clary sage which is consistent with the product label. [98] In addition, the compounds present also indicate the use of citrus fruits, coriander, turmeric, Lantana camara, Ceylon ironwood, liverwort, cinnamon, cardamon, juniper, lemon grass, chilli, patchouli, angelica, valeriana, sandalwood and pine.

Table 2. Composition of DoTerra Peace® essential oil.

Retention time (min)	Compound	% Composition	Present in Tisserand® lavender	Potential source
6.39	2-Thujene	1.73	Y	Marjoram [56] [67] [85]
6.58	A-pinene	16.78	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] Chamomile [48] [50] [88] [97]
6.96	camphene	0.16	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] Chamomile [48] [50] [88] [97]
7.57	A-phellandrene	0	Y	Marjoram [56] [67] [85]
7.63	A-phenllandrene	1.87	N	Marjoram [56] [67] [85]
7.71	(1S,5S)-(-)-2(10)-pinene	1.23	N	Unknown
8.08	A-myrcene	0.61	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] Chamomile [48] [50] [88] [97]
8.45	3-Thujene	0.25	N	Marjoram [56] [67] [85]
8.61	3-carene	0.21	N	Lavender [46] [55] [63] [84]
8.79	p-mentha1,4(8)-diene	0.76	N	Solvent
9.02	O-cymene	0.72	Y	Lavender [46] [55] [63] [84]
9.13	D-limonene	2.86	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
9.22	Eucalyptol	0.38	Y	Lavender [46] [55] [63] [84]
9.37	Trans-a-ocimene	1	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
9.66	A-ocimene	0.72	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
9.97	C-terpinene	1.24	Y	Marjoram [56] [67] [85]
10.28	Cis-a-terpineol	0.44	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
10.41	trans linalool oxide	0.12	Y	Lavender [46] [55] [63] [84]
10.81	A-terpinene	0.28	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]

Continued

10.86	cis linalool oxide	0.11	Y	Lavender [46] [55] [63] [84]
11.27	linalool	25.3	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
11.48	1-octenyl acetate	0.24	Y	Lavender [46] [55] [63] [84]
11.83	3-octyl acetate	0.28	Y	Lavender [46] [55] [63] [84]
11.95	2-carene	0.11	N	Marjoram [56] [67] [85]
12.46	(-)-Alcanfor	0.09	Y	Lavender [46] [55] [63] [84]
12.62	(+)-4-carene	0.04	N	Unknown
13.12	Isoborneol	0.59	N	Marjoram [56] [67] [85]
13.42	Terpinen-4-ol	5.25	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
13.72	Butanoic acid hexyl ester	0.1	Y	Lavender [46] [55] [63] [84]
13.8	A-terpineol	1.74	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
13.92	trans-2-Norbornanol	0.21	N	Unknown
14.27	N-octyl acetate	1.14	N	Found in citrus fruits
15.61	Linalyl acetate	30.93	N	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
15.86	Geranyl vinyl ether	0.15	N	Coriander [63]
16.38	Bornyl Acetate	0.25	N	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84]
16.45	Geranyl acetate	1.34	Y	Lavender [46] [55] [63] [84]
17.72	C-elemene	0.09	N	Turmeric [100]
18.04	Copaene	0.22	N	Marjoram [56] [67] [85]ylang ylang [60] [63] [79] [94]
18.41	nerol acetate	0.22	Y	Lavender [46] [55] [63] [84]
18.64	Ylangene	0.23	N	ylang ylang [60] [63] [79] [94]
18.74	A-cubecebe	0.84	N	Unknown
18.92	Geranyl acetate	2.19	N	Marjoram [56] [67] [85] ylang ylang [60] [63] [79] [94]
19.17	A-selinene	0.55	N	Marjoram [56] [67] [85]
19.66	Germacrene B	0.16	N	Marjoram [56] [67] [85] ylang ylang [60] [63] [79] [94]
19.74	Cos-a-bergamontene	0.22	Y	Lavender [46] [55] [63] [84]
19.94	Caryophyllene	12.73	Y	Marjoram[56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
20.13	C-Amorphene	0.21	N	Lantana camara [57]
20.19	Isoledene	0.22	N	Ceylon ironwood [52] [53]
20.26	Trans-a-bergamotene	0.18	N	Sandalwood [63] [67] [80] [96]

Continued

20.47	Guaia-6,9-diene	0.23	N	Liverwort
20.61	Prezizaene	0.41	N	Vetiver [47] [69] [83] [89] [90]
20.77	Cis-a-fernesene	3.74	Y	Lavender [46] [55] [63] [84]
21.24	Dehydro-aromadendrene	0.38	N	Frankincense [87]
21.33	C-muurolene	0.93	N	Marjoram [56] [67] [85] ylang ylang [60] [63] [79] [94]
21.48	Germacrene D	12.35	Y	Marjoram [56] [67] [85] Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
21.68	A-guaiene	1.81	N	Unknown
21.76	(+)-cyclosativene	1.04	N	Marjoram[56] [67] [85] ylang ylang [60] [63] [79] [94]
22.02	A-farnesene	0.41	N	Marjoram [56] [67] [85] ylang ylang [60] [63] [79] [94]
22.06	A-bisabolene	1.37	Y	Lavender [46] [55] [63] [84]
22.24	C-cadinene	0.86	Y	Lavender [46] [55] [63] [84] ylang ylang [60] [63] [79] [94]
22.45	4-diene-cadina-1(10)	3.79	N	Cinnamon [76]
22.94	A-calacorene	0.32	N	unknown
23.11	hedycaryol	0.57	N	Camellia brevistyla [64]
23.21	8,9-dehydro-cycloisolongifolene	2.66	N	Chinese sage [73] black cardamon [97]
23.43	cis-eudesm-6-en-11-ol	2.3	N	Vetiver [47] [69] [83] [89] [90]
23.63	2,3,4,4a,5,6,7,8-octahydro-1-1,4aa,7a,tetramethyl-1H-benzocyclohepten-7-ol	0.27	N	Unknown
23.94	caryophyllene oxide	0.9	Y	Lavender [46] [55] [63] [84]
23.99	3,5,11-eudesmatriene	0.75	N	Vetiver [47] [69] [83] [89] [90]
24.14	A-acorenol	0.64	N	Chinese juniper [65]
24.39	Khusimone	1.23	N	Vetiver [47] [69] [83] [89] [90]
24.81	Selin-6-en-4a-ol	6.29	N	lemon grass [71] [93]
24.96	C-himachalene	0.84	N	Chilli [95]
25.06	Isovalencenal	1.25	N	Vetiver [47] [69] [83] [89] [90]
25.29	cadinol	1.49	Y	ylang ylang [60] [63] [79] [94]
25.55	muurolol	7.55	N	Lavender, [46] [55] [63] [84], ylang ylang [60] [63] [79] [94]
25.7	C-gurjunese oxide	1.84	N	Angelica [72]
25.85	Cedr-8-en-13-ol	1.96	N	Vetiver [47] [69] [83] [89] [90]
26.03	Zizanol	1.85	N	Vetiver[47] [69] [83] [89] [90]
26.19	Khusiol	1.53	N	Vetiver [47] [69] [83] [89] [90]
26.52	Eudesm-7(11)-en-4-ol	2.24	N	Ephedra sinica, Chenopodium botrys, wild sage [82] [98]
26.9	A-patchoulene	1.32	N	Patchouli [54] [59] [62]

2.3.3. Aroma Diffusion

The oils were diffused for participant inhalation via a Tisserand® fan diffuser. Eight drops of the essential oil were placed on the diffuser pad and the diffuser put on the high setting for 45 minutes prior to testing to infuse the room with the aroma. Two pads were required, one for each of the two different aroma conditions.

2.3.4. The State-Trait Anxiety Inventory, Spielberger (1970), the S-Form

The STAI-S is a 20-item scale measures state anxiety on a 4-point Likert scale ranging from 1 (*Not at all*) to 4 (*very much so*). The scale is a reliable and valid measure with alpha > 0.86 for internal consistency and r values > 0.73 for content validity [102]. Participants rate how they feel in that exact moment relative to each item. A total score is arrived at by appropriately reverse scoring some items and summing the responses. Given the repeated measures element of the study, the S form of the STAI is appropriate as it is more responsive to change than the T form [41].

2.3.5. State Anxiety-Inducing Video

The video used was of a young female domestic violence victim being forcibly restrained by several police officers after refusing them entry to her home. The female was distressed and accompanied by another female who was also distressed. After the police failed to provide a warrant, she blocked her door. Forced entry took place and she was then restrained and positioned on the floor whilst officers made a search of the property. The researcher and supervisor selected this video due to its potential to induce anxiety in participants.

2.3.6. Eye-Witness Questions

A series of six questions were asked to participants as part of the distraction from the true nature of the study, and to add further stress to the induction task. An example item from this was:

"*How many police officers were present*?"

The researcher and supervisor developed the questions to have an eye-witness testimony style, ensuring the participants paid close attention to the video. These questions assured the participants that they were participating in an eye-witness testimony study.

2.4. Ethical Consideration

Participants were recruited under the premise that they would partake in an eye-witness testimony style study. The advertisement and information sheet stated that the purpose of the study was to investigate the accuracy of recall among adults after witnessing a potential crime whilst controlling for mood. Recruitment under this premise was undertaken to eliminate any expectancy effects that participants may have possessed regarding aromas, ensuring the state anxiety measure remained valid. This was revealed and the reasons behind the deception were explained at the debrief, and participants were informed of the true aims. Finally, this study took place in a post-COVID-19 period. Therefore,

safety procedures in line with a COVID-19 risk assessment were used throughout. This study received ethical approval through the Northumbria University Ethical Approval system #36874.

2.5. Procedure

In the aroma conditions the diffuser was switched on for forty-five minutes prior to participant arrival. This time ensured each participant inhaled air fully infused with the aroma of essential oil in their testing session. Participants were tested individually. The first state anxiety questionnaire was completed prior to entering the test room. They were then led into the test room, the lights were switched off, and participants were instructed to watch the video closely as they would be answering question on the events in it later. The anxiety-inducing video lasted 13 minutes. Immediately after this, participants were asked six eye-witness testimony style questions, delivered in the same order in each session, asked to write their answers on a piece of paper. Then, participants completed the second state anxiety questionnaire. Finally, participants were fully debriefed and any questions answered.

2.6. Procedure for Analysis

Initially, the raw data were screened to ensure there was no missing data, reverse scoring was applied for items 1, 2, 5, 8, 10, 11, 15, 16, 19 and 20 of the STAI-S and all items were summed to give total state anxiety scores for both pre- and post-video timepoints. A 2 (pre to post) × 3 (aroma condition) mixed factorial ANOVA was used to investigate the main effect of the aroma condition, the main effect of the pre to post repeated measures factor and the interaction effect of the pre to post and aroma condition. All analyses were carried out in SPSS version 26.0. No participants were removed due to missing data or the presence of outliers.

3. Results

Descriptive statistics are presented in **Table 3**. The two-way mixed ANOVA revealed a significant effect for the anxiety-inducing video on the pre to post anxiety scores, Wilks Lambda = 0.642, $F(1, 57) = 31.802$, $p < 0.001$, $\eta p^2 = 0.358$. Before watching the video, participants reported less state anxiety (M = 32.80) than following the video (M = 41.45). The main effect of condition was not significant, $F(2, 57) = 0.459$, $p = 0.612$, $\eta p^2 = 0.017$. Similarly, the time-point * condition interaction effect was non-significant, Wilks Lambda = 0.955, $F(2, 57) = 1.343$, $p = 0.269$, $\eta p^2 = 0.045$. Although the interaction was not significant, the mean scores suggest that there is a potential impact of the aromas in terms of anxiety buffering, (**Figure 2**). Calculation of Cohen's d values was performed between the lavender and control mean post scores, d = -.428, 95% CI [−1.052, 0.202] a small, approaching medium effect based on Cohen's criteria, the *Peace*® and control mean post scores, d = −0.335, 95% CI [−958, 0.291] between a small and medium effect, and between the mean post scores of the aroma conditions, d = 0.075, 95% CI [−0.545, 0.695], no effect.

Table 3. Mean (SD) state anxiety scores N = 60.

Condition	Peace N = 20	Lavender N = 20	Control N = 20
Pre-Anxiety induction	33.05 (11.63)	32.45 (8.71)	32.90 (10.15)
Post-Anxiety induction	40.10 (13.68)	39.15 (11.39)	45.10 (16.04)

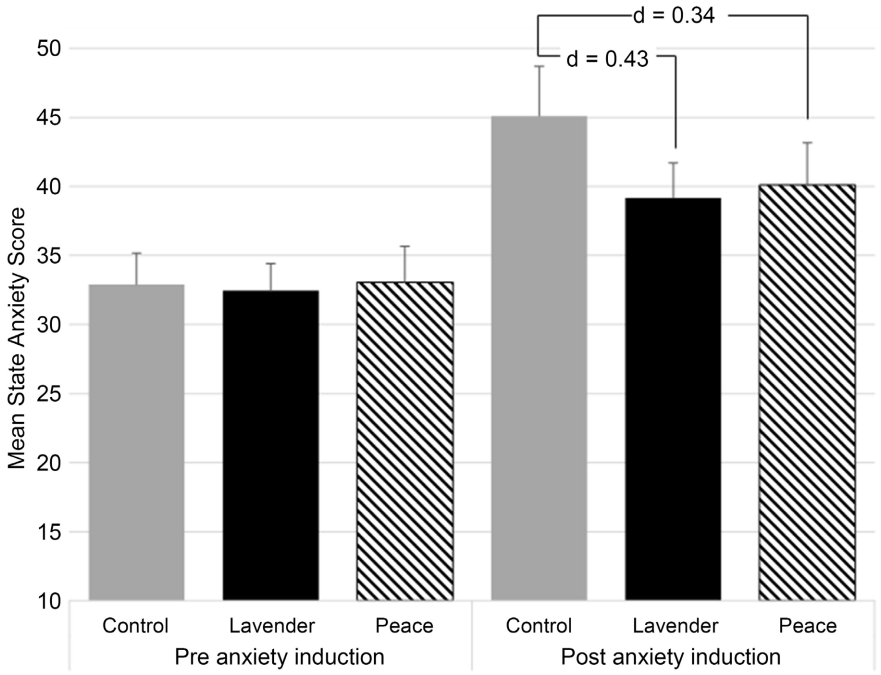

Figure 2. Pre- and post-state anxiety scores in the "Peace" "lavender" and "control" conditions. Error bars indicate standard errors.

4. Discussion

The current study investigated the effects of ambient aroma on induced anxiety in a sample of healthy adults. The main focus of the study was the relative potential for anxiety buffering from the two aromas compared to a no aroma control group. In particular, whether a blend may offer greater buffering potential than a single essential oil was of interest. First, we hypothesised that viewing the video would increase state anxiety levels. The analysis highlighted that the video indeed had a significant anxiety inducing effect, with a large effect size. Moreover, we hypothesised that both the lavender and *Peace*® aromas would mitigate the anxiety induction when compared to a control group. The interaction effect testing this hypothesis did not reach statistical significance. However, although these findings appear to diverge from previous work reporting significant effects of pure lavender and lavender blends upon anxiety, consideration of effect sizes indicates small beneficial impacts of lavender and the *Peace*® blend on the post video anxiety scores when compared to the control condition. Given the presence of these effects that align in direction with previous findings, this may suggest the current study was underpowered.

The value of identifying a simple and successful means of anxiety induction should not be understated. The gold standard method of anxiety induction has hitherto been the Trier Social Stress Test (TSST). Kirschbaum, Pirke and Hellhammer [103] created a social stress test consisting of two sections, initially the anticipation period where researchers ask a participant to prepare for an interview, lasting around 5 minutes. Then the testing phase begins with a mock interview which lasts for 5 minutes, followed by a 5-minute mental arithmetic task. Participants complete these tasks in front of an audience of two to three judges. Research has found that the TSST is an efficacious method of anxiety induction [104], yet it is financially and physically costly [105]. In contrast, the current study employed an anxiety induction technique that appears equally effective yet is simple and inexpensive. This illustrates the potential for researchers to administer this procedure in a wide range of study protocols without the need for extensive investment in skilled labour.

The failure to find support in terms of statistical significance for the impact of the aromas is disappointing although we would argue that it represents a lack of power in the study rather than an absence of any real effect. When calculating the required sample size, we based the expected effect size on that reported in a meta-analysis by Kim and Suh [45]. However, closer scrutiny indicates that the analysis was based on measures of the stress response, and although large effect sizes have been reported for anxiety [19], smaller effect sizes as found here are also seen in previous literature focusing on anxiety, e.g. Wilkinson, Love, Westcombe, Gambles, Burgess, Cargill, Young, Maher and Ramirez [106]. Taken together, this suggests that the current study may have been underpowered, and we contend that the consistent pattern of effects reported here suggest the presence of a real anxiety buffering effect of aroma inhalation.

Kritsidima, Newton and Asimakopoulou [19], reported an effect of d = 0.94 for ambient lavender aroma against a control when participants were exposed to lavender for an unspecified length of time. The smaller effect reported here was observed following an exposure period of 20 minutes. The potential difference in length of exposure may have impacted the observed effect as serum levels of linalool, an anxiolytic compound found in lavender, rises in proportion to the exposure period [107]. A further study found that inhaling lavender diffused from a cotton ball taped to participants' gowns for an average of 85 minutes had a small (d = 0.30) beneficial anxiolytic effect when measuring pre-to-post across 150 participants [20]. Although it is not possible to be certain, it seems likely that the strength of aroma from a cotton ball would be lower than that of ambient dispersal, and as such linalool absorption may have been similar here to that in Braden and colleagues' study. Accordingly, minimum recruitment analyses may be more appropriately based upon the small effect size found by Braden *et al.* This produces a recommended minimum sample of 162, almost three times the sample size collected. This supports the potential that the current study was underpowered. Repeating the procedures outlined in this study with a larger sample would be interesting to confirm this.

Furthermore, it should be considered that anxiety is a complex human experience consisting of two dimensions of experiences and emotions, from the affective anxious arousal of fear and distress to the more cognitive aspect of anxious apprehension characterised by the experience of worrying [108]. These dimensions may not be equally responsive to management methods such as aromatherapy. Kritsidima, Newton and Asimakopoulou [19] found a significant beneficial effect of lavender on state anxiety, but also discussed the differential impact lavender had on the affective and cognitive components. They proposed that the anxiolytic effects of lavender aroma are only present for affective dimensions. In retrospect, the anxiety induction employed in the current study may have prompted the more cognitive aspects of anxiety, with participants experiencing test-like anxiety in the bogus eye-witness testimony situation [109] rather than feeling emotional anxiety in response to the distressing video. Such a situation may have blunted the impact of the aromas. Future research may consider alternatives to the recall test technique employed here but should also consider that intentionally provoking affective dimensions of anxiety may be less ethical than cognitive dimensions as they may be more distressing for participants.

This current study addressed many methodological problems of the previous body of literature, most notably the common absence of measuring pre-to-post, which may have impacted the clarity of the effectiveness of previously reported interventions. Lehrner, Marwinski, Lehr, Johren and Deecke [18] carried out a study investigating the effects of lavender compared to a control in a dentist's office, concluding that lavender significantly reduced anxiety levels. However, they only measured the participants' anxiety levels once, within twenty minutes of arrival. Even after randomly assigning participants to either a control or experimental group, there is the potential that there are imbalances in the baseline anxiety scores between the two groups, independent of any experimental stimulus [110]. Collecting data at the baseline permits evaluation of any differences pre-treatment, and then measuring post-treatment ensures that the researchers measure the level change, eliminating the potential influence from baseline imbalances [111].

This leads to the potential issue of a lack of standardised aroma administration across previous research, which may result in variance in findings between studies. As aromatherapy can be delivered using procedures such as deep inhalation, diffusion, or topical administration methods such as massages [112] the method of administration is one difference across aromatherapy research. Chen, Fang and Fang [113] administered lavender aroma by placing the oil in a small bottle pinned to participants' chests, thus inhaling almost directly from the bottle, and concluded that lavender aroma significantly reduced anxiety. The present study, however, diffused the lavender oil in the air through a fan diffuser for 45 minutes prior to testing. Participants may have inhaled a notable difference in essential oil concentration between inhaling from the bottle and inhaling diffused aroma in the air. Research with mice has suggested that there is a thre-

shold of concentration required to see an anxiolytic effect with lavender oil [114]. Further research supported this suggestion, whilst also narrating the role of the serotonergic system in the anxiolytic effect of lavender oil [115]. Together their conclusions stipulate that there is a minimum concentration required to pass into the bloodstream and eventually reach the neurotransmitter systems in the brain. As participants in the Chen *et al.* study were likely to inhale a much stronger concentration when compared to the diluted method of fan diffusion, the anxiolytic mechanism of lavender oil was potentially enhanced. However, the fan diffusion ensured participants were blinded, whereas the bottle pinning may have created a level of expectancy among Chen *et al.*'s participants. Therefore, the differences in findings may be traced to utilising an administration method that protected the blinding protocol but diluted the concentration of lavender oil that participants inhaled.

The *Peace*® blend produced an effect that was indistinguishable from that of lavender. This was a key aspect of the study as previous work employing blends has shown that they are capable of reducing anxiety but did not investigate a comparison to pure lavender oil eg Conrad and Adams [31]. Additionally, their investigation did not include any blinding procedures. As previously mentioned, failure to blind may result in participants gaining a level of expectancy as participants are fully aware of the researcher's aims and expectations. Howard and Hughes [116] demonstrated this within aromatherapy research by employing a priming technique, manipulating expectancies regarding the aroma's potential influence on their level of relaxation. When expecting the aroma to relax them, participants relaxed more and vice versa. Thus, biases in their responses are seen directly from their expectancy [117]. To eliminate these influences participants were unaware of the true aims of the current study.

The current study adds to previous literature by employing a novel anxiety induction procedure coupled with a subjective self-report scale to measure levels of anxiety. Hongratanaworakit [118] used physiological parameters to measure anxiety when investigating the effects of a lavender-bergamot blend, finding significant reductions in heart rate and blood pressure after topical administration. However, research has discussed that the data from self-report and physiological parameters do not always align outside of aromatherapy [119]. Within aromatherapy, one study found significant improvements in self-report measures in response to aromatherapy, yet no significant changes in their physiological markers [120]. Coupled with the potential that the physiological parameters of anxiety may inadvertently measure other influences such as cognitive effort [121], the misalignment between self-report and more objective measures in aromatherapy research may explain the inconsistency in the findings. However, aromatherapy is utilised to promote feelings of wellbeing [40]. Thus, becoming aware of the effect aroma has upon subjective experience is arguably more valuable within aromatherapy research.

Moreover, the lack of standardisation for a procedure to assess aromatherapy may limit the findings throughout the aromatherapy research area. To date,

there are no standardised procedures outlining the amount and concentration of aroma required, the method of administration, or the temperature of the room where testing is taking place. Although it is acknowledged that this may be difficult to develop and may take away from the reality of aromatherapy practice, developing a degree of standardisation for aromatherapy research will allow for consolidation and comparison of findings with a more consistent set of procedures, improving the reliability and validity of the conclusions.

Moss and Oliver [122] outline three potential mechanisms for the way aromas work. The first potential mechanism states that the qualia of the aroma, specifically how pleasant we perceive the aroma will impact our mood and performance. The next potential mechanism suggests that the olfactory bulb links to the brain and after inhaling the aromatic oil, brain areas such as the amygdala and limbic system are stimulated. Finally, the third potential mechanism suggests that after inhalation, the volatile compounds in the aroma pass into the blood stream and are delivered to the brain, impacting the neurotransmitter systems. As the current study was not designed to investigate the proposed mechanisms, the results could be explained by any or all of these suggestions. Future researchers should use brain imaging and blood serum analysis to investigate the mechanisms of aromas. Investigating the way aromas work will push the available knowledge in the aroma research area creating a crucial pathway for future aromatherapy use.

5. Conclusion

In conclusion, the current study has identified a novel method of anxiety induction that could be employed in future studies of this kind. Importantly, small to medium-sized beneficial effects were found for anxiety mitigation by both pure lavender and *Peace*® blend aromas suggesting their potential usefulness as self-care interventions. The popularity of aromas and essential oils is ever-growing, highlighting the importance of scientifically investigating their impact to ensure informed use. The possible benefits to be gained from such self-care interventions range from relieving pressure on health services to boosts in the economy as a consequence of reduced absenteeism and increased consumer spending. Such possibilities should not be overlooked.

Conflicts of Interest

The authors report there are no competing interests to declare.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author, [MM], upon reasonable request.

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