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MODULATION OF COGNITIVE PERFORMANCE AND MOOD BY AROMAS OF PEPPERMINT AND YLANG-YLANG

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This study provides further evidence for the impact of the aromas of plant essential oils on aspects of cognition and mood in healthy participants. One hundred and forty-four volunteers were randomly assigned to conditions of ylang-ylang aroma, peppermint aroma, or no aroma control. Cognitive performance was assessed using the Cognitive Drug Research computerized assessment battery, with mood scales completed before and after cognitive testing. The analysis of the data revealed

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significant differences between conditions on a number of the factors underpinning the tests that constitute the battery. Peppermint was found to enhance memory whereas ylang-ylang impaired it, and lengthened processing speed. In terms of subjective mood peppermint increased alertness and ylang-ylang decreased it, but significantly increased calmness. These results provide support for the contention that the aromas of essential oils can produce significant and idiosyncratic effects on both subjective and objective assessments of aspects of human behavior. They are discussed with reference to possible pharmacological and psychological modes of influence.

Keywords aroma, cognition, memory, mood, peppermint, ylang-ylang

INTRODUCTION

Putative effects of various aromas on aspects of human behavior can be traced back to ancient Greece, where the extracts of aromatic plants were used for cosmetic, religious, and medical purposes. Today the popularity of aromas for pleasure, relaxation, and in therapeutics is unabated and typified in the ever popular application of aromatherapy (Tisserand, 1993). Valnet (1986) documents the historical clinical use of aromatherapy as a treatment for various mood-disorders and the introduction of "modern" aromatherapy in Europe can be traced back to Rene-Maurice Gattefosse in the 1920s (Wartik, 1995). Proponents of aromatherapy claim complex and far-reaching benefits of essential oils—extracted and highly refined fragrant substances produced by some plants—with each oil purported to possess quite exclusive properties. Despite such widespread belief in the beneficial properties of aromatherapy among the populace however, there has to date been limited scientific research into the validity of such reputed effects.

Within the relatively small body of investigative research that exists, findings thus far indicate that the claims made for essential oils may indeed have some validity. Regarding therapeutic subjective effects, Martin (1996) reported decreases in anxiety levels in patients undergoing computerized-axial-topography (CAT) scans while in the presence of ambient heliotropin, a vanilla-like odor, relative to controls. Similarly, the sedative reputation of lavender has been evidenced in studies of anxiety reduction and mood improvement in a range of situations (Lorig & Schwartz, 1987; Ludvigson and Rottman, 1989; Buchbauer et al., 1991; Lehrner et al., 2005). Itai et al. (2000) compared the effects of lavender and hiba oil on female patients with chronic haemodialysis and found hiba oil to significantly decrease mean levels of anxiety and depression, where lavender was found only to exert a beneficial effect on anxiety alone. It is worth noting however that no benefit was present in a study investigating the effect of aroma on anxiety in pre-procedural abortion patients (Weibe, 2000). Further to investigations of subjective mood, Brownfield (1998) reported that massage with topical administration of lavender resulted in more pronounced analgesic effects than massage alone among patients with chronic rheumatoid arthritis. In addition to studies of sedative or relaxing aromas, peppermint, jasmine, and rosemary oils have all shown arousing properties in keeping with their collective reputation (Warm & Dember, 1990; Kovar et al., 1987).

Employing more objective dependent measures, Diego et al. (1998) found electroencephalogram (EEG) readings to show increased beta-power following lavender inhalation, implying neurological sedation and corroborating subjective reports of calmness, whereas jasmine has been demonstrated to produce increased alpha-power in the frontal cortices, indicative of increased arousal (Wartik, 1995). Furthermore, peppermint appears capable of reliably producing small EEG and electromyogram (EMG) or muscular-conductance fluctuations during REM and NREM sleep (Badia et al., 1990), a finding that is able to rule out the possible effects of expectancy.

The long-believed possibility that essential oils may influence performance in cognitive domains has also received some attention. Degel and Koster (1999) found inhalation of lavender to improve letter counting and mathematical tasks, relative to inhalation of jasmine, whereas both extracts impaired creativity performance relative to controls. Furthermore, Degel et al. (2001) described a beneficial effect of lavender and orange aromas on a measure of implicit memory. Warm et al. (1991) reported both peppermint and muguet essences increased performance on a sustained visual attention task. Ilmberger et al. (2001) explored the psychological component of performance effects and ventured interlinked correlations between subjective evaluation of substances and corresponding expectations, relative to task performance. The authors contend that their results clearly assign a high psychological component to the effects of essential oil aromas. This is somewhat in contrast to the findings of Itai et al. (2000) and Warm et al. (1991) who argue for independent effects on cognition that are separate to mood changes and further suggests avenues of effect independent of psychological beliefs and expectations. Moss et al. (2006) found a complex pattern of relationships between induced expectancies and aroma effects when investigating the influence of chamomile aroma on cognition and mood. The findings support to some extent those previously identified elsewhere for the impact of expectation on physiological measures under aroma conditions (Campenni et al., 2004).

In a previous investigation, Moss et al. (2003) compared cognitive performance across lavender, rosemary or control conditions using a computerised assessment battery. Lavender was found to globally impair memory and reaction times, whereas rosemary was found to improve the overall quality of long-term memory. With regard to subjective mood states, both control and lavender groups became significantly less alert than the rosemary group over the test session. In apparent contrast, Field et al. (2005) report improved mathematical computation speed following lavender exposure, however—an effect they suggest is a result of improved mood and greater relaxation. In a more applied setting Sakamoto et al. (2005) found that although sedating, lavender could improve work performance when applied during rest sessions, possibly by improving the quality of relaxation.

A recent assessment of the effect of ylang-ylang aroma on physiological parameters and subjective state demonstrated a possible "harmonization" effect illustrated through reductions in blood pressure and heart rate accompanied by increases in alertness and attentiveness (Hongratanaworakit & Buchbauer, 2004). However, no assessment of cognitive functioning was made. The accrued evidence therefore generally supports the proposal of substance-specific effects on subjective state, physiological measures, and to some extent cognitive performance. To extend knowledge in the area, this study attempted to further assess the impact of peppermint (*Mentha piperita*), and ylang ylang (*Cananganga odorata*) essential oil aromas on a wide range of cognitive performance measures and subjective mood.

MATERIALS AND METHODS

Participants

One hundred and forty-four undergraduates and members of the general public volunteered to take part in this study. The composition of the three experimental groups was: peppermint condition 24 females (mean age 24.4 years, SD 5.6), 24 males (mean age 24.7 years, SD 5.0); ylang-ylang condition 26 females (mean age 22.8, SD 5.1); 22 males (mean age 24.3, SD 6.0); control condition 28 females (mean age 24.5, SD 6.3), 20 males (mean age 21.9 SD 8.3). Prior to participation each volunteer completed a health questionnaire. All participants self reported that they were in good health and none were excluded from the study.

Aromas

"Tisserand" pure essential oils (Tisserand Aromatherapy, Newtown Road, Hove, Sussex, BN3 7BA) of peppermint and ylang-ylang were used to produce the ambient aromas. Four drops of the appropriate oil (or water in the control condition) were applied to a diffuser pad for a “Tisserand Aroma-stream.” The Aroma-stream was placed under the bench in the testing cubicles so as to be out of sight, and switched on for five minutes prior to the testing of each participant. Each aroma was above detection threshold and of approximately equivalent strength for each testing session as assessed by an independent party.

Testing Cubicles

Each testing cubicle measured 2.4 m long $\times$ 1.8 m wide $\times$ 2.4 m high and were maintained at a temperature between 18 and 22 degrees Celsius throughout the testing sessions.

Cognitive Measures

A tailored version of the Cognitive Drug Research (CDR) computerized assessment system (installed on Viglen genie computers) was employed to evaluate cognitive performance. The CDR system includes a number of measures that are specific to particular aspects of attention, working memory and long-term memory. Stimuli are presented on a color monitor, and (with the exception of word recall) responses are made using a simple response module containing two buttons labelled “Yes” and “No” respectively. A suite of programs controls all aspects of testing, including selection of appropriate sets of stimuli for presentation and recording all responses.

The tests employed in this study were presented in the following order.

Word Presentation. A series of 15 words is presented sequentially for one second each with an inter-stimulus interval of one second. The words are a mix of one two and three syllables.

Immediate Word Recall. The computer display counts down sixty seconds during which time participants write down as many of the words from the list as possible. Recall is scored for number of correct words, and errors (words not presented in the list).

Picture Presentation. Twenty photographs are presented, with a stimulus duration of 2 s each, and inter stimuli interval of 1 s.

Simple Reaction Time. The word Yes is presented in the center of the screen. The participant has to press the Yes button as quickly as possible. There are

50 trials and the intertrial interval varies randomly between 1 and 2.5 s. The reaction time is recorded in ms.

Digit Vigilance. A number is displayed constantly to the right of the screen. A series of 240 digits is presented one at a time in the center at a rate of 80 per minute; 45 match the constantly displayed digit. The participant has to press the Yes button as quickly as possible every time the digit in the center matches the one constantly displayed. Accuracy of response (%), reaction time (ms), and number of false alarms are recorded.

Choice Reaction Time. Either the word Yes or the word No is presented in the center of the screen. The participant has to press the Yes or No button as appropriate and as quickly as possible. There are 30 trials (25 "Yes" and 2 "No") and the intertrial interval varies randomly between 1 and 2.5 s. Accuracy (%) and reaction time (ms) are recorded.

Spatial Working Memory. A schematic picture of a house is presented for 5 s. The house has nine windows in a 3×3 pattern, 4 of which are illuminated. A series of 36 presentations of the same house in which just one window is illuminated follow, and the participant has to respond Yes if the window was one of the four lit in the original presentation, or No if it was not. Sixteen of the stimuli require a Yes response and 20 a No response. Reaction time and accuracy are recorded and a sensitivity index calculated.

Memory Scanning. Five digits are presented singly at the rate of one every second for the participant to remember. A series of thirty digits is then presented. For each, the participant must press Yes or No according to whether the digit is thought to be one of the five presented initially. Fifteen stimuli require a Yes response and 15 a No response. This is repeated three times using a different 5 digits on each occasion. Reaction time is recorded and a sensitivity index calculated.

Delayed Word Recall. The computer counts down 60 s during which time participants free recall as many of the words from the list as possible. Recall is scored for number of correct words; and errors (words not presented in the list).

Word Recognition. The 15 words initially presented for the word recall are presented again in random order interspersed with 15 new words. The participant presses Yes or No each time to signal whether or not the word was from the original list. Reaction time and accuracy are recorded and a sensitivity index calculated.

Picture Recognition. The 20 pictures presented earlier are shown again in random order interspersed with 20 similar new ones. The participant signals recognition by pressing the Yes or No button as appropriate. Reaction time and accuracy are recorded and a sensitivity index calculated.

"Pencil and Paper". *Visual Analogue Scales*, assessing subjective levels of alertness, calmness, and contentedness, were presented prior to and following the computerized tests. Participants are required to indicate their current state by marking a line drawn between two bipolar adjectives. The entire battery took approximately 25 min to administer.

Primary Cognitive Outcome Measures

The aforementioned measures were collapsed into four global outcome factors, and two sub-factors derived from the battery by factor analysis, as previously utilized (Kennedy et al., 2000, 2001; Wesnes et al., 1997, 1999, 2000).

Quality of Memory. Derived by combining the percentage accuracy scores (adjusted for proportions of novel and new stimuli where appropriate) from all of the working and secondary memory tests—spatial working memory, numeric working memory, word recognition, picture recognition, immediate word recall, and delayed word recall (with adjustments to the total percentage correct for errors on the latter two tasks). One hundred percent accuracy across the six tasks would generate a maximum score of 600 on this index.

Examination of the factor pattern suggests that this global "quality of memory" factor can usefully be further divided into two sub-factors: "working memory" and "secondary memory"

Working Memory Sub-Factor. Derived by combining the percentage accuracy scores from the two working memory tests—spatial working memory, and numeric working memory. One hundred percent accuracy across the two tasks would generate a maximum score of 200 on this index.

Secondary Memory Sub-Factor. Derived by combining the percentage accuracy scores (adjusted for proportions of novel and new stimuli where appropriate) from all of the secondary memory tests—word recognition, picture recognition, immediate word recall and delayed word recall (with adjustments to the total percentage correct for errors on the latter two tasks). One hundred percent accuracy across the 4 tasks would generate a maximum score of 400 on this index.

Speed of Memory. Derived by combining the reaction times of the four computerized memory tasks—numeric working memory, spatial memory, delayed word recognition, and delayed picture recognition (units are summed milliseconds for the four tasks).

Speed of Attention. Derived by combining the reaction times of the three attentional tasks—simple reaction time, choice reaction time, and digit vigilance (units are summed milliseconds for the three tasks).

Accuracy of Attention. Derived by calculating the combined percentage accuracy across the choice reaction time and digit vigilance tasks with adjustment for false alarms from the latter test. One hundred percent accuracy across the two tasks would generate a maximum score of 100.

The contribution of individual task measures to each of these factors and sub factors is illustrated schematically in Figure 1.

Subjective Mood Measure: The Bond-Lader Visual Analogue Scales (Bond & Lader, 1974)

The 16 visual analogue scales of Bond-Lader were combined as recommended by the authors to form three mood factors: “alert,” “calm,” and “content.”

Procedure

Participants were approached individually and asked if they would help in the validation of a new cognitive test battery. No mention of aromatherapy or essential oils was made. This deception was carried out in order to avoid the possibility of expectancy effects contaminating the data. Recruitment took place one week prior to testing and participants were randomly and unknowingly allocated to one of the three conditions, peppermint, lavender, or no odor (control). They were then given a time and day on which to attend the laboratory. Testing took place in three different cubicles, and on three different days of the week (Monday, Wednesday, and Friday) to avoid cross-contamination of odors. On arrival at the lab each participant was once again reminded that they were there to assist in the validation of the new test battery, and to try their best on

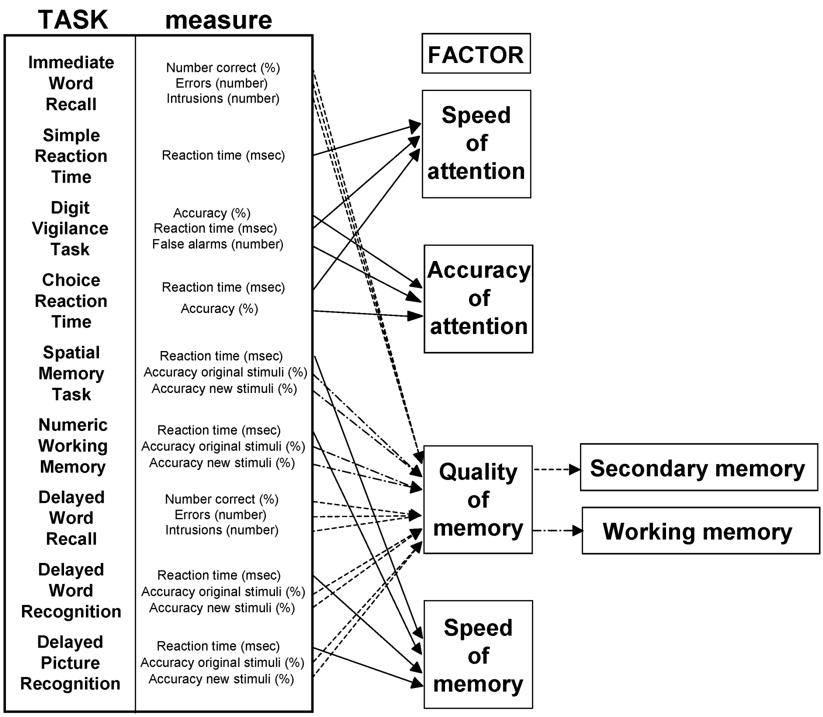

Figure 1. Schematic representation of the CDR battery showing (from left to right) running order of tasks, individual task outcome measures, and the composition of the four factors derived by factor analysis. Arrows indicate that a task outcome measure contributes to the given factor "Speed of Attention," "Accuracy of Attention," "Quality of Memory," or "Speed of Memory." Dotted lines indicate contribution to both "Quality of Memory" and to either "Working Memory" (-.-) or "Secondary Memory" (- - - -), respectively.

all the tasks. They were then asked to complete the mood scale to supposedly assess if the tasks affected mood. Participants were then taken into the cubicle where they completed the CDR battery followed by a second mood scale. Finally they were debriefed regarding the true nature of the experiment, and any questions answered. If any of the participants commented on the presence of an odor prior to or during the testing session, the researcher dismissed it with responses of the kind: "nothing to do with me" and "don't know where it came from." No participants indicated at any time that they felt the odor had affected them at all, or that they thought the study was investigating the effect of odor on performance or mood.

Statistics

Scores from the individual task outcome measures were combined to form the four global outcome measure factor scores and the secondary memory and working memory factor scores. These and the individual task outcome measures making up the factors were analysed using the statistical package Minitab 12 for Windows. The one way analysis of variance (Anova) followed by Tukey pairwise comparisons was employed to identify where any differences between the three conditions may have existed. Analysis of subjective mood was made in a similar manner on the pre to post testing difference scores, reflecting any changes in mood state due to exposure to the aromas and/or as a result of completing the assessment battery.

RESULTS

The analyses of the individual task outcome measures that make up the factors are presented in Table 1. The results described here will concentrate on the primary cognitive outcome measures described earlier.

Quality of Memory Factor

An independent groups Anova revealed a significant difference between groups, $F(2,141) = 6.21$; $p = 0.003$. Tukey post-hoc comparisons identified that the peppermint condition (mean = 381.91) scored significantly higher than both the ylang-ylang condition (mean = 336.08), $p < 0.01$, and the control condition (mean = 351.1), $p < 0.05$, (Figure 2a). No other significant differences were found.

Secondary Memory Sub-Factor

An independent groups Anova revealed a significant difference between groups, $F(2,141) = 3.90$; $p = 0.022$. Tukey post-hoc comparisons identified that the peppermint condition (mean = 204.69) scored significantly higher than the ylang-ylang condition (mean = 174.27), $p < 0.05$, (Figure 2b). No other significant differences were found.

Working Memory Sub-Factor

An independent groups Anova revealed a significant difference between groups, $F(2,141) = 3.84$; $p = 0.024$. Tukey post-hoc comparisons identified that the

Table 1. Effects of peppermint and ylang-ylang essential oils on individual task outcome measures from the CDR battery. The units are number of correctly recalled items for the word recall tasks, milliseconds for the reaction times. The sensitivity indices are calculated using the non-parametric signal theory index (SI) presented by Frey and Colliver (1973)

Outcome variable	1) Control Mean ± s.d.	2) Peppermint Mean ± s.d.	3) Ylang-Ylang Mean ± s.d.	Significant comparisons
Immediate word recall correct	5.62 ± 2.09	6.10 ± 2.41	5.30 ± 1.91	2 vs. 3*
Immediate word recall errors	0.51 ± 0.38	0.54 ± 0.71	0.48 ± 0.55	
Simple reaction time	248.29 ± 33.78	248.17 ± 44.26	270.21 ± 39.56	1 vs. 3*, 2 vs. 3*
Number vigilance accuracy	94.86 ± 7.56	96.94 ± 6.59	92.10 ± 10.53	2 vs. 3*
Number vigilance false alarms	1.14 ± 0.77	1.00 ± 1.22	1.54 ± 1.57	
Number vigilance reaction time	380.26 ± 32.63	367.72 ± 41.88	394.92 ± 48.03	2 vs. 3*
Choice reaction time	398.86 ± 53.14	390.11 ± 61.02	411.62 ± 63.71	
Spatial memory sensitivity index	0.91 ± 0.10	0.91 ± 0.10	0.85 ± 0.27	
Spatial memory reaction time	888.9 ± 248.0	904.8 ± 424.1	1060.1 ± 492.4	
Numerical working memory sensitivity index	0.83 ± 0.11	0.87 ± 0.12	0.85 ± 0.14	
Numerical working memory reaction time	710.5 ± 140.1	728.4 ± 202.5	807.6 ± 293.9	
Delayed word recall correct	3.67 ± 2.03	4.28 ± 2.80	3.21 ± 2.70	
Delayed word recall errors	0.42 ± 0.77	0.52 ± 1.05	0.69 ± 0.97	
Word recognition sensitivity index	0.58 ± 0.11	0.66 ± 0.23	0.60 ± 0.31	
Word recognition reaction time	769.4 ± 212.7	883.6 ± 394.5	905.6 ± 257.3	1 vs. 3*
Picture recognition sensitivity index	0.63 ± 0.24	0.69 ± 0.19	0.62 ± 0.16	
Picture recognition reaction time	845.7 ± 183.6	914.7 ± 235.0	970.8 ± 233.0	1 vs. 3*

*$p < 0.05$.

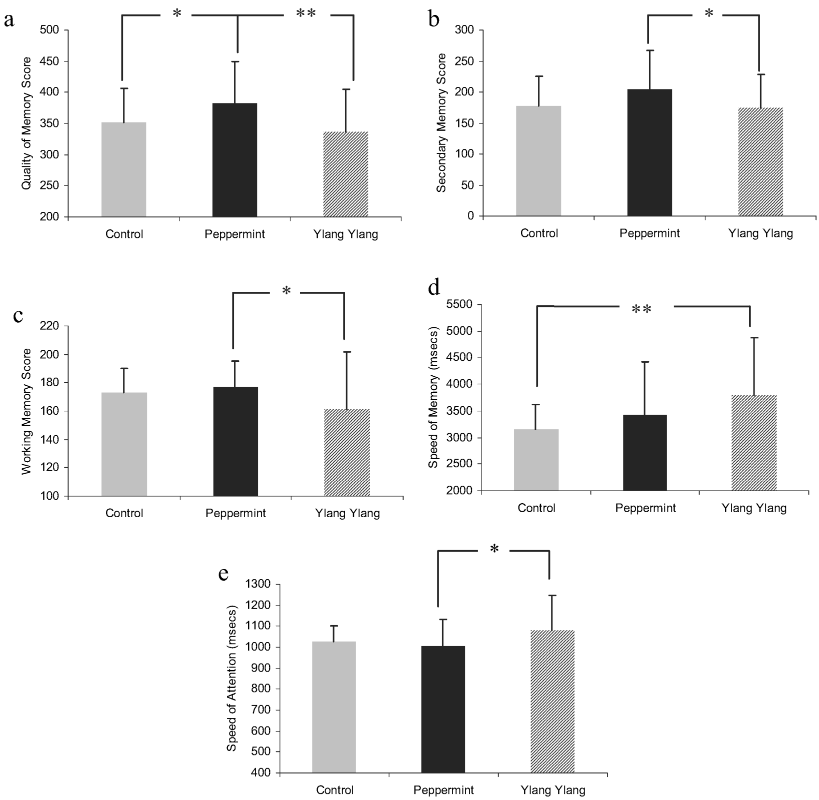

Figure 2. Effects of peppermint and ylang-ylang on the cognitive factors derived from the CDR test battery: (a) "Quality of Memory," (b) "Secondary Memory," (c) "Working Memory," (d) "Speed of Memory," and (e) "Speed of Attention" (see text for details). Figures depict mean values. Error bars represent standard deviations. $^{*}p < 0.05$; $^{**}p < 0.01$.

peppermint condition (mean = 177.23) scored significantly higher than the ylang-ylang condition (mean = 161.81), $p < 0.05$, (Figure 2c). No other significant differences were found.

Speed of Memory Factor

An independent groups Anova revealed a significant difference between groups, $F(2,141) = 6.08$; $p = 0.003$. Tukey post-hoc comparisons identified that the control condition (mean = 3152.1 ms) was significantly quicker than the ylang-ylang condition (mean = 3785.7 ms), $p < 0.01$, (Figure 2d). No other significant differences were found.

Speed of Attention Factor

An independent groups Anova revealed a significant difference between groups, F (2,141) = 4.45; $p = 0.013$. Tukey post-hoc comparisons identified that the peppermint condition (mean = 1006.0 ms) was significantly quicker than the ylang-ylang condition (mean = 1078.9 ms), $p < 0.05$, (Figure 2e). No other significant differences were found.

Accuracy of Attention Factor

An independent groups Anova revealed no significant differences between groups, $F(2,141) = 2.79$; $p = 0.065$.

Subjective Mood Measures

Analysis of the pre-test ratings indicated no differences to exist between the three conditions on any of the mood variables prior to the experimental session: *Alertness,* $F(2,141) = 1.11$; $p = 0.331$. *Contentedness,* $F(2,141) = 0.48$; $p = 0.620$. *Calmness,* $F(2,141) = 0.39$; $p = 0.678$. Subsequent analyses compared post-test minus pre-test change in mood scores.

Alertness

An independent groups Anova revealed a significant difference existed between groups, $F(2,141) = 3.33$; $p = 0.039$. Tukey post-hoc comparisons identified that the peppermint condition produced a small increase in alertness (mean change = 0.74) compared to a decrease in the ylang-ylang condition (mean change = –6.93), $p < 0.05$, when participants had completed the test battery, (Figure 3a). No other significant differences were found.

Calmness

An independent groups Anova revealed a significant difference existed between groups, $F(2,141) = 5.49$; $p = 0.005$. Tukey post-hoc comparisons identified that the ylang-ylang condition produced an increase in calmness (mean change = 1.92) compared to a decrease for both the control condition (mean change =

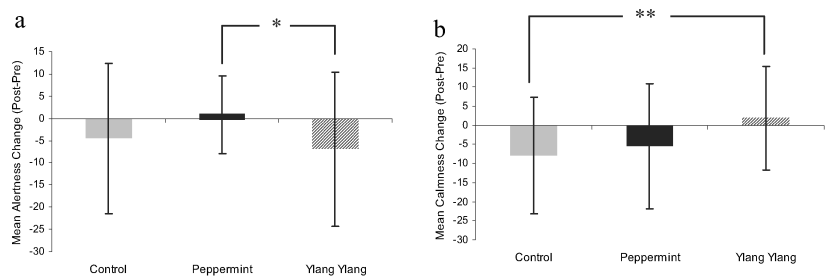

Figure 3. Effects of peppermint and ylang-ylang on change in self-rated mood as measured using the Bond-Lader Visual Analogue Scales: (a) "Alertness" and (b) "Calmness." Figures depict mean change (post-test minus pre-test ratings) such that a positive change represents an increase on that dimension over the test session. Error bars represent standard deviations. $^{*}p < 0.05$; $^{**}p < 0.01$.

–7.87) $p < 0.01$, and the peppermint condition (mean change –5.47) $p < 0.05$, when participants had completed the test battery, (Figure 3b). No other significant differences were found.

Contentedness

An independent groups Anova revealed no significant differences between groups, $F(2,141) = 0.1.46$; $p = 0.236$.

DISCUSSION

The results of this study clearly support the contention that the aromas of essential oils can modulate mood and cognitive performance in healthy adult volunteers. Furthermore, the effects observed somewhat reflect the properties historically attributed to the aromas of these essential oils. Ylang-ylang is widely regarded as possessing sedative and calmative properties (Tisserand, 1993), and is commonly found in products aimed at aiding relaxation. Such a proposition was supported by the increase in "calmness" reported here by participants in the ylang-ylang condition compared to those in both the control and peppermint conditions. The possible stimulating effect of peppermint aroma was only partially supported. A significant difference in the alertness mood dimension was isolated between the two aroma conditions, with peppermint producing a small increase and ylang-ylang a decrease. However, although the control condition also reduced alertness, when compared to peppermint the difference did not quite reach significance ($p = 0.06$). No effect was found on the contentedness dimension, although an increase might have been hypothesized for either or both aromas.

This pattern of subjective mood results was broadly reflected in the effects on the factors derived from the assessment of cognitive performance across the three conditions. An aroma that increases alertness may be expected to enhance cognitive performance, and one that increases calmness to impair it, albeit not universally (e.g., Field et al., 2005). Peppermint produced a significant improvement in overall quality of memory, compared to both control and ylang-ylang conditions. This factor derives from the accuracy scores from all the tasks of long term and working memory and the improvement versus controls only existed when all these tasks were considered together in this factor. If the secondary (long term) and working memory sub-factors are considered separately, peppermint was only found to be significantly enhance performance when compared to ylang-ylang. These differences appear to be a reflection of the combination of the enhancement and impairing properties of the two aromas, respectively. Interestingly, the improvement in accuracy of memory for peppermint was not at the cost of speed. The speed of memory factor indicated that ylang-ylang slowed reaction times significantly compared to controls. Peppermint, however, produced no significant change in this factor.

The factors derived from the tests of attention revealed a similar pattern of results. For the speed of attention factor, ylang-ylang produced the slowest reaction times, significantly so when compared to peppermint that produced the quickest. No significant differences were revealed between the conditions for the accuracy of attention factor.

Peppermint has also been demonstrated to enhance performance on a range of physical exercise tasks (Raudenbush et al., 2001). The authors propose that the effects are due to the aroma producing a change in (an unidentified dimension of) mood and consequently in the level of motivation of the participants. Although a small increase in alertness was recorded for peppermint aroma in the current study, this was not significant compared to controls. It is therefore unlikely that the recorded improvement in memory performance was due to changes in mood or motivation. In addition, if motivation had been responsible it might have been expected to impact those tasks with a low cognitive load, that is, reaction times. The data reveal that this was not the case, with no significant differences existing between the peppermint and control conditions for either the speed of attention or speed of memory factors.

If the influence of the aromas of essential oils on cognition is not a consequence of changes in mood related to characteristics of the aroma itself, then an alternative needs to be considered. A direct pharmacological action would require the absorption of volatile compounds into the blood and their subsequent activity at a neuronal level. Although the level of active compounds that may be absorbed from an ambient aroma through the lungs and nasal mucosa is low when compared to other modes of administration, monoterpene components of rosemary have been detected in the blood of rodents exposed to the vapors of this essential oil (Jirovitz et al., 1990, 1992; Kovar et al., 1987). An attractive aspect of a pharmacological mechanism for the affect of aromas on cognition is the concept of substance-specificity. Such a concept would fit neatly alongside the results reported here, with each aroma delivering a unique pattern of influence on the cognitive factors described. In support of the pharmacological influence of plant-based compounds research has provided evidence that is pertinent here. Wake et al. (2000) demonstrated that sage and melissa possessed neuropharmacological activity. Specifically, on the nicotinic and muscarinic acetylcholine systems in homogenate preparations of human cortical cell membranes. There is of course a long-established link between the cholinergic system and memory, and it may be the case that other plants such as peppermint and rosemary also possesses such activity. Such a possibility remains to be investigated further at a neurochemical level.

Recent work with animals also supports the proposal that volatile organic plant constituents can have direct pharmacological effects on behavior and physiology. Compounds that emanate from the leaves of certain deciduous trees such as the oak have been collectively termed “green odour” and this has been shown to attenuate stress induced activation of the hypothalamo-pituitary-adrenal (HPA) axis in rats (Akutsu et al., 2002). Such activation results in persistent hyperthermia, which is significantly diminished by inhalation of green odor.

An interesting comparison can be made to the results of the current study to those reported by Moss et al. (2003) regarding the effects of rosemary and lavender aromas on the same cognitive and mood assessments. Lavender aroma was found to produce decrements in performance on secondary memory, speed of memory, and speed of attention compared to controls. In contrast rosemary only significantly enhanced secondary memory performance. With regard to mood rosemary increased alertness compared to lavender and controls, and lavender and rosemary both increased contentedness compared to controls. These effects bear similarities to, but importantly also distinct differences to the patterns observed here. Such findings support the contention that each essential oil may possess it’s own idiosyncratic pattern of influence. This would be consistent with the aroma therapist’s view and may be a result of the proportions and structure of the constituent volatile compounds.

Indeed, from the data presented here and evidence from elsewhere it seems plausible that the effects observed in studies of the aromas of essential oils may be a result of a combination of pharmacological, cognitive, and emotional effects. The area is still ripe for further investigation.

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