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# EFFECTS OF A LEMON AROMA ON ATTENTION, REACTION TIME AND MOOD

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## ABSTRACT

**Background:** The literature on aromas and mood and cognition shows that effects may depend on the method of presenting the aroma, aroma type, duration and the outcome measures examined. The present study examined the effects of a lemon aroma produced by a commercial diffuser on mood, a focused attention choice reaction time task and a categoric search choice reaction time task. **Method:** Forty-four university students completed the study. Participants carried out one session with a lemon aroma and one with no aroma. The order of conditions was counterbalanced. **Results:** The accuracy of identifying the presence of an aroma was at a chance level. Those in the aroma condition reported a more positive mood (higher hedonic tone scores) both before and after the performance tests. Those in the aroma condition were more accurate but slower. They also showed faster encoding of new information. **Conclusion:** The present study has shown that exposure to a lemon aroma is associated with a morepositive hedonic tone, more accurate performance, and faster encoding of new information but a slower motor response. Further research is required to identify the mechanisms underlying such effects and evaluate the practical relevance of these changes.

**KEYWORDS:** Lemon; Aroma; Mood; Selective Attention; Choice Reaction Time; Errors; Encoding of new information; University students.

## INTRODUCTION

Aroma therapy aims to elicit behavioural responses and mood alterations through the use of essential oil. Recent research has supported this claim, and one consequence of this is the rise in the commercial market for air freshening products. Many of these

commercial products (some based on essential oils but most chemically based) have adopted aspects of aromatherapy by advertising 'relaxing' and 'soothing' products for the living area and 'revitalising' and 'uplifting' products for the kitchen and bathroom areas. For example, a range of plug-in diffusers are available, and each fragrance contains specially selected essential oils which are claimed to have an enhancing effect on your mood.

Psychological research has reported mood alterations when exposed to aromas,[1] and it has been widely acknowledged that aroma can also affect aspects of cognitive function.[2,3] Research has examined the effects of odour on risk-taking,[4] memory,[5] complex and simple mental tasks,[6] and goal setting.[2] There are two major questions about these commercial aroma products that need to be addressed. First, how effective are these air freshening products? Does the use of aroma in the environment actually change mood in any way? Or is it the case that we are buying into the mass commercial market by purchasing products which may not have the desired effect? Secondly, can the use of aroma make living and working environment more pleasant? We are increasingly living indoors due to increased technology and longer office working hours. One consequence of this is Sick Building Syndrome (SBS). Although the causes and manifestations of this are currently speculative, they are a group phenomenon and cause symptoms linked to the indoor environment.[7] The question of whether office environments can be improved and made more tolerable and/or more productive is therefore of importance. Research has suggested that both excessive heat and poor air quality[8] may be partially responsible for the prevalence of SBS. The present study may, therefore, contribute not only to the growing volume of research on olfactory effects on behaviour but may prove useful in devising new methods of overcoming SBS.

Olfaction has, in comparison with the other senses of the body, had relatively little attention.[8] Humans have a less keen sense of smell than many other non-human primates, and our olfactory system is no longer crucial for survival. We are, however, able both to detect minute differences in odour intensity and to distinguish between some 10,000 different odours. It has been suggested that the primary reason we cannot detect an odour is due to problems in memory retrieval, not due to an insufficient sense of smell. Thus, human perception guides our olfactory system, creating perceptions from molecules which enter the nostrils. The biological pathway relevant to the present topic is where and how odour molecules interact with the human brain in order to affect mood and cognition.

Gaseous molecules enter the nostril and travel to the olfactory mucosa. Here, they contact receptor neurons, which, in turn, contact receptor proteins- the active site of olfaction. An opening of ion channels then triggers an electrical signal which travels to the olfactory bulb of the brain. The olfactory bulb connects to the olfactory cortex area and has links with the limbic system. The limbic system primarily governs memory storage, emotion and behaviour, whereas the cortex is concerned with conscious thought. It is, therefore, plausible that aromas may influence areas of emotion and cognition. Moreover, olfactory projections synapse more directly and specifically with the amygdala-hippocampal complex than do afferents from any other sensory modality.[9] Whether different aromas may have different effects, possibly via stimulating differing brain regions, will be discussed later.

Early theorists held interesting views regarding the impact of aroma on the state of body and mind. Pouchet, in 1779, for example, reported the dangers of odours and attributed one woman's death to keeping a bouquet of lilies in her room overnight.[10] Though clearly inaccurate, this nevertheless demonstrates how we have changed our thinking about odour. It was suggested as early as 1931 that pleasant odours have a retroactive facilitative effect on learning, and unpleasant odours have a retroactive inhibitory effect.[10] Since then, it has been widely recognised that odour can, in some situations, have some effect on emotion and mood. Recent findings have, however, produced mixed results, ranging from aromas having either a positive effect to them having no effect at all.[11] Methodologies and odour delivery may partially explain this lack of consistency.

There are several ways in which olfaction may be related to mood and emotion. Numerous authors suggest that both emotion and olfaction rely on similar neural circuits and are, therefore, intrinsically linked. Secondly, in terms of memory, sources suggest certain aromas may elicit forgotten memories of the past. A third mechanism, and the most relevant here, is that aromas may characteristically change a person's mood and/or behaviour. In contrast to how we regard other senses, odours are generally assumed to rate either as 'pleasant' or 'unpleasant': It has proven very difficult to find an odour which is consistently rated as neutral.[12] This is useful from a methodological perspective as one can simply expose a person to a 'type' of aroma and then measure the outcome. It is important to note, however, that 'mood' comprises many aspects: studies both define and measure this 'umbrella' term differently. Few studies to date have focused exclusively on the effects of odour pleasantness on mood, yet many have included this as part of a wider study.

One study[11] used three conditions (pleasant, unpleasant and no odour) and examined their effect on mood, perceived health and four performance tasks (multiplication, addition, odd-word and proofreading). Odour delivery was from two hidden fan units, which turned on randomly six times, each for one-minute periods. This is an example of ambient sporadic delivery. The pleasant aroma condition consisted of both lemon and ylang. The results were not significant in that the odours did not influence any of the tasks. The unpleasant odour condition had a negative effect on perceived mood, health and performance, but this was explained by saying that people believe bad odours may be harmful and, thus, participants actually exhibit physical symptoms as a function of this belief. Other research[13] supports this finding, and the explanation was that the odour itself may not have been the direct cause of a worse mood but that the odour may have indirectly influenced persons with certain characteristics and traits. Subjectively reported feelings are of relevance when explaining the use of commercial air fresheners and dispensers. People using these products may not be improved physiologically, yet they may subjectively 'feel better' in themselves. Hence, the present study measured both a subjective outcome, namely mood, and an objective one, namely cognitive function.

Another study[14] compared the effects of a supposed 'alerting' aroma (peppermint) and an assumed 'relaxing' aroma (bergamot) with no aroma control. They measured performance on a vigilance task where participants were required to press a button as soon as a target stimulus was detected. Results showed a significant difference between the relaxing aroma and the control, but there was no such difference between the alerting aroma and the control, indicating that peppermint does not improve sustained attention. However, this study had a major limitation in that the laboratory was only scented five minutes prior to experimentation. Participants may not have been exposed to the alerting aroma long enough for it to have an effect. The present study kept an essential oil diffuser at a set level throughout the period of experimentation.

A number of studies have been more specific about when aroma affects performance. Ho and Spence[15] reported that aromas may only facilitate performance under more demanding (dual task) experimental task conditions. Specifically, they noted that peppermint odour did not have a conventional alerting effect (defined as participants becoming faster yet less accurate) and that the aroma increased concentration only in a complex task, which, in turn, led to more correct responses and better performance. Another study[16] reported that

complex tasks were adversely affected by polluted air. Specifically, the number of errors that were detected by participants in a proofreading (complex) test was lower in a malodour condition. A simple task (basic arithmetic) was not, however, affected by the polluted environment that was introduced into the laboratory. The explanation was that simple tasks require less effort and attention, and therefore, one can deal adequately with other environmental stressors, such as odours. These two studies suggest that pleasant aromas only have a beneficial effect during complex tasks and that unpleasant aromas only have a detrimental effect during complex tasks. In addition, Baron and Kalsher[1] studied the time course effects of aromas on mood. They reported significant findings when participants filled in a mood questionnaire five minutes after entering a laboratory. However, detectable mood shifts were not produced after only two minutes of exposure to the aroma. Furthermore, Baron and Kalsher[1] describe how pleasant aroma may paradoxically lead to a decrease in task performance. Firstly, the positive affect produced by the aroma induces a general lack of concentration or a tendency to think about other unrelated but pleasant experiences. Secondly, participants may not want to engage in a mundane or boring task, which may rid them of this positive affect. A final and relevant point is made by Ludvigson and Rottman, which refers to habituation.[17] Having studied the effect of cloves and lavender on "fundamental psychological processes", detrimental cognitive functioning was reported with lavender, yet this did not appear in a second test session. This highlights the potential methodological problem of habituation and how it may affect results. Olfactory adaptation in humans can take place so rapidly that it progresses to a state in which the organism may become completely insensitive to an odour.[18]

Taken as a whole, the studies reviewed above present a mixed set of results. It can, under some circumstances, be assumed that odours may influence mood. Questions remain, however, about the importance of factors such as type of odour, odour delivery and duration of exposure. Another point of interest is whether odour can influence mood or cognition without participants realising that odours are being presented. The current study did not inform participants that there was an ambient aroma. The oil diffuser was hidden in the laboratory, and participants were only notified of its presence during debriefing. Odours may be stimulating areas of the brain without us being subjectively aware,[5] which is relevant for theories that provide possible biological mechanisms for how an odour may affect mood and cognition.

The first major biological review of psycho-aromatherapy, "The action of essences on the nervous system", was published in the 1920s by Gatti and Cayola.[19] They reported that odours affect mood and emotion via the nerve endings of the olfactive mucosa, and lemon is named as one such stimulating essence. Furthermore, researchers have suggested the use of lemon oil to treat depression.[20] Numerous biological pathways may be relevant here as the olfactory tract branches and connect with approximately 12 other areas of the brain, including the amygdala, hippocampus and limbic system. These connections are often hypothesised to provide a biological mechanism for the mood-altering effect of aromas, although little data has firmly proven this. Walter found an electrical phenomenon in the brain referred to as Contingent Negative Variation (CNV), which is an upward shift occurring in the brain waves when the person is expecting something to happen.[21] Walter found that a jasmine aroma, which is said to have uplifting properties, increased the amplitude of CNV, whereas lavender, often claimed to have a sedative effect, decreased the CNV amplitude. This may be one plausible and objective measure of how odours influence brain activity and is, therefore, relevant to the cognitive tasks measured in the current study.

Differences have also been observed in brain function between sniffing and smelling an odour. The current study, in contrast to previous ones,[3] is concerned with ambient aroma; thus, it is smelling as opposed to active sniffing. Results cannot, therefore, be easily generalised from studies which use different types of odour delivery. Specifically, Sobel et al.[22] found that the two methods activate two different areas of the brain, with the dissociation between regions activated by olfactory exploration (sniffing) and regions activated by olfactory content (smell) showing a distinction in brain organisation in terms of human olfaction.

The present study investigated the effects of a lemon aroma, which has been previously used in behavioural research.[1,11] Many companies use citrus-based products, and lemon is known for its 'invigorating' and 'refreshing' properties, which are rated as pleasant. Gordon (1925) got a sample of 200 people to rate ten odours and found lemon to be the most pleasant.[10] Findley (1942) had his sample rate 19 odours, and, again, lemon was the overall preferred odour.[10] Essential oil, as opposed to a commercial brand, was used in the present study. Although it is doubted whether essential oils are wholly 'natural', they are generally modified versions of natural oils.[23] A pleasant aroma was used in the present study, as it mimics more

accurately the use of commercial air diffusers and can thus be more readily used in both the work and home environment.

The aim of this study was to investigate the effect of lemon aroma on aspects of cognition and mood. Mood ratings led to three separate components: anxiety, alertness and hedonic tone. Hedonic tone has been viewed as the 'defining feature' of affective experience.[24] Also of interest is establishing whether lemon aroma is pleasant 'relaxing' or pleasant 'alerting'. Participants were exposed to both an 'aroma' condition and a 'no aroma' condition and asked to complete a battery of tests. They were also asked at the end of the experiment if they noticed the presence of any aroma. Two different yet identical laboratories were used, so there was no need to carry out different conditions of the experiment on different days, as previous studies have done.

Two hypotheses were tested. The first was that the presence of a pleasant ambient aroma would significantly increase positive affect and alertness but significantly decrease anxiety. The second was that the presence of a present ambient aroma would significantly increase concentration (as measured by mean accuracy and the number of errors) yet significantly decrease reaction time (as measured by both speed of encoding and mean reaction time).

## METHOD

The study was carried out with the informed consent of the volunteers and the approval of the School of Psychology Ethics Committee, Cardiff University.

### *Study design*

Each participant carried out a test session with an aroma and one without an aroma. Half the participants had the sessions in the order of aroma/no aroma, and the others were in the opposite order.

### Pilot study

Twenty participants were briefly exposed to two different aromas to see which made them feel more alert and awake. Both the lemon essential oil and peppermint essential oil were used in the pilot, and, on average, 80% of participants felt the lemon made them feel (1) more energetic, (2) more awake and (3) more alert. It was thus decided to use lemon aroma in the main study.

***Participants***

Fifty students who attended Cardiff University were recruited. Six were excluded due to a high number of errors (30 or more) on the performance tasks. Their mean age was 20 years, and ages ranged from 18-32 years. Participants carried out the study in return for course credit. Participants who signed up were randomly assigned to the condition they would take part in first, and all participants took part in both conditions of the study. The final sample consisted of 35 females and nine males.

***Aromas***

The oil diffuser was made by 'Melange', an American-based company; the oils were from 'The Body Shop'. The diffuser could be set to five different settings (it remained on the highest setting) and produced a subtle ambient aroma throughout the laboratory.

***Experimental tasks***

All of the tests were presented on IBM-compatible PCs. Completion of the whole battery of performance tests took approximately 25 minutes.

***Mood rating***

Mood was rated both before and after the performance tests using bi-polar visual analogue rating scales (e.g. Drowsy-Alert, Happy-Sad, Tense-Calm). These scales have been used to measure changes in state produced by noise, time of day, caffeine, meals, minor illnesses, stress and fatigue.[25-34]

***Focused attention choice reaction time task***

This selective attention task was developed by Broadbent[35,36] and has been widely used to study changes in state.[37-46] Target letters appeared as upper case A's and B's. In each trial, three warning crosses were presented on the screen, and the outside crosses were separated from the middle one by either 1.02 or 2.60 degrees. Participants were told to respond to the letter presented in the centre of the screen and ignore any distractors presented in the periphery. The crosses were on the screen for 500 msecs and were then replaced by the target letter. The central letter was either accompanied by 1) nothing, 2) asterisks, 3) letters that were the same as the target, or 4) letters that differed. The two distractors were identical, and the targets and accompanying letters were always A or B. The correct response to A was to press a key marked A on the left-hand side of the response box, while the correct response to B was to press the key marked B on the right-hand side of the response box. Participants were

given ten practice trials followed by four blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled. The variables analysed here were errors, mean reaction time and the encoding of new information (the difference between alternations and repetitions of targets).

***Categoric search choice reaction time task***

This task was also developed by Broadbent[35,36] to measure aspects of selective attention and has been widely used to study changes in state.[37-46] Each trial started with the appearance of two crosses in the positions occupied by the non-targets in the focused attention task (i.e. 2.04 or 5.20 degrees apart). Participants did not know which of the crosses would be followed by the target. The letter A or B was presented alone on half the trials and was accompanied by a digit (1-7) on the other half. Again, the number of near/far stimuli, A versus B responses and digit/blank conditions were controlled. Half of the trials led to compatible responses (i.e. the letter A on the left side of the screen or the letter B on the right), whereas the others were incompatible. Participants were given ten practice trials followed by four blocks of 64 trials. In each block, there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distractor conditions. The nature of the previous trial was controlled. The variables analysed here were errors, mean reaction time and the encoding of new information (the difference between alternations and repetitions of targets).

***Detection and Pleasantness of aromas***

At the end of the study, the participants were asked if they had detected any aromas during either session. If they had detected an aroma, they were asked to rate the pleasantness of it.

**RESULTS**

The SPSS statistical package was used to analyse the data. A mixed ANOVA was carried out, with the order of conditions as the between-subject factor and aroma v no aroma as the within-subject factor.

The manipulation of the independent variable, aroma, proved successful. 45% of participants noticed the aroma in the correct condition (i.e., they answered that they only noticed the aroma in the first condition when that was when the aroma was present). 48% of participants did not notice the aroma present at any point in the experiment. 7% of participants either believed there to be an ambient aroma when there was not or vice versa.

***Errors***

The results of the ANOVA revealed that there was a statistically significant main effect of condition on the number of errors in the focussed attention task, with greater accuracy in the aroma condition (Aroma mean = 13.2 SE = l.0; No Aroma mean = 17.9 SE = l.5; F (1, 42) = 11.42, p<.002). This effect of the aroma on accuracy was significant for trials with no distracting letters (F (1, 42) = 7.89, p<0.008) and when there was a distracter present (F (1, 42) =5.91, p<0.019).

Results showed that the mean number of errors was also significantly decreased by the aroma in the categoric search task (Aroma mean = 14.8 SE=l.1; No Aroma mean = 19.4 (SE = 1.4) F (1, 42) = 19.78, p<.001)

***Speed of encoding new information***

Further analysis showed that the aroma condition also had a significant effect on the speed of encoding (the difference in RT between response to a different stimulus to the previous trial and a repetition of the stimulus; lower scores represent faster encoding of new information) in the focused attention test (Aroma mean = 15.9msec SE =2.9; No Aroma mean = 28.3msec SE =3.7; F (1,42) = 20.84, p<.001).

***Mean reaction time***

The mean reaction time was significantly increased in the aroma condition of the focused attention computer task, both when the target was presented alone (Aroma mean = 402.8msec SE =6.1; No Aroma mean = 386.3 SE=5.4; F (1, 42) = 18.44, p<0.001) and when it was presented with a distracter (Aroma mean = 414.3 msec SE =6.6; No Aroma mean = 394.2msec SE = 5.6; F (1, 42) = 22.65, p<0.001). Aroma also significantly increased reaction time in the categoric search test, but only when the target was presented alone (Aroma mean = 539.7 msec SE =7.6; No Aroma mean = 507.0 SE=6.8; F (1, 42) = 82.51, p<0.001).

***Mood***

These analyses examined both the effects of aroma condition and pre/post-performance ratings. There was a statistically significant main effect of both conditions (F (1,42) = 9.41, p<.004) and pre/post (F (1, 42) = 33.77, p<0.01) on hedonic tone. The results are shown in table 1.

**Table 1: Effects of aroma on ratings of hedonic tone before and after the performance tests (higher scores = more positive mood; scores are the means, se in parentheses).**

| Pre-tests Aroma | Pre-tests No Aroma | Post-tests Aroma | Post-tests No Aroma |
|---|---|---|---|
| 198.0 (6.3) | 170.5 (7.2) | 182.0 (6.2) | 168.5 (5.8) |

Time of the rating (pre/post) had the only significant effect on alertness, showing the participants became less alert after the task battery, regardless of condition ($F(1, 42) = 35.75$, $p<0.01$). The anxiety ratings showed no significant effects.

## DISCUSSION

The results of this study have not fully supported either part of the hypothesis, and the results can be summarised as follows. The aroma significantly increased hedonic tone but had no effect on either alertness or anxiety. The non-significant effect of the aroma on alertness has been reported in previous research.[14] The results of the cognitive tasks indicated that concentration was increased with the aroma, but there was a mixed effect of the aroma on reaction time. Specifically, the presence of aroma significantly decreased the number of errors made and the speed of encoding in the focused attention task. The presence of the aroma also significantly increased the mean accuracy both when a target was presented alone and when a distracter was present. The mean reaction time, however, was significantly slower in the aroma condition. This shows that the aroma changed the speed error trade-off towards a more accurate, slower performance. The encoding of new information was faster in the aroma condition, showing that there was an attentional effect as well as a speed-error trade-off.

In general, the results support the widely accredited hypothesis that aromas can have an effect on mood and cognition and provide insight into the type of circumstances under which aroma may have its effect. In support of Ehrlichman and Bastone,[12] lemon was consistently rated as a pleasant odour (the average rating was 7 out of 10 by those who noticed it). Interestingly, the majority of participants noticed the aroma when the debriefing form was given, including those who never noticed it during the experiment. This indicates that had the participants been aware of the nature of the experiment, their subjective mood ratings may have been different.

The question of whether lemon aroma is a 'pleasant-alerting' odour, as opposed to a 'pleasant relaxing' odour, cannot be fully answered. There was a speed-accuracy 'trade-off, which is

considered a standard alerting effect,[15] but no effect of the aroma on alertness or anxiety. The significant increase in hedonic tone when exposed to the aroma just supports the view that the lemon aroma induces a general positive state.

It was speculated that the presence of aroma might increase positive affect, which would then be associated with increased alertness and, thus, better cognitive performance. This was partially supported as the increase in hedonic tone was coupled with increases in accuracy and a reduction in the number of errors made. In accordance with the view of Baron and Kalsher,[1] the reported increase in hedonic tone may have led to a more accurate but slower performance. The rate at which new information was processed (speed of encoding) increased due to the presence of ambient aroma, but participants remained 'laid back' with regards to physically pressing the buttons on the response box in both computer tasks, hence the slower reaction times.

Prior research led to the prediction that a pleasant aroma would have a more pronounced effect on a 'complex' task. This was not seen in the present study; more significant results were yielded from the simpler of the two tasks, the focused attention task. Neither Ho and Spence's[15] nor Rottons's[16] results were supported, and three explanations are provided to account for this. First, it may have been the case that participants did, in fact, find both the computer tests simple or complex. The definition of 'complex' should, therefore, be explicitly described in further research. Secondly, lemon, as a pleasant, relaxing aroma, might lead to a profile of performance change that is independent of the complexity of the task. Finally, habituation to an aroma, which was not observed here, may be linked to task complexity.

It has been stated that lemon could be used to treat depression, and the present increase in hedonic tone supports this. The increase in hedonic tone supports the idea that the olfactory tract branches with parts of the limbic system; however, there was no corresponding increase in the two other measures of mood, alertness and anxiety. This study, therefore, calls into question whether the olfactory tract branches specifically with the amygdala. This area of the limbic system appears to be central to our experience of anxiety, and unpleasant odours activate the left amygdala significantly more than pleasant odours, indicating that (from an evolutionary perspective) there is more need for an unpleasant odour to produce a feeling of anxiety and, thus, stimulate the amygdala, than a pleasant odour. This idea, however, warrants further investigation.

Lemon oil has been shown to reduce the Contingent Negative Variation, indicating that it has a relaxing or sedative effect on the brain. However, the presence of a lemon aroma may not, therefore, be relaxing or alerting but may simply act as a distraction for participants during task performance. Different methodologies in studies lead to differing results. There are three main variables responsible for this. The first is the type of odour used. The use of lemon has been found to affect mood and performance in the present study and in that of Baron and Kalsher,[1] yet when mixed with ylang essential oil, it produced no significant results.[11] One explanation for this is the suggestion that an odour mixture alters the pattern of brain activity in comparison to the single odour compound on its own during some cognitive tasks. The second major variable is the type of odour delivery. The majority of studies now use ambient aroma to mimic home environments. There are numerous different ways to achieve ambient aroma, such as via sprays, diffusers, oil burners and fan units. The present study found that ambient aroma was preferable to any other mode of delivery as participants did not need to be informed of the use of the aroma until after the completion of the study. Ambient delivery produces different effects from more direct and intrusive methods of odour delivery, and constant ambient aroma may have the opposite effect to a sporadically delivered ambient aroma. Baron and Kalsher[1] used the former method of delivery and reported significance, whereas Knasko[11] used the latter method and found no significant effects. This finding is contradictory to the concept of "mental refreshment"[14], which stipulates that sporadically administered aroma may 're-alert' participants at regular points during an experiment, thus improving their performance on certain tasks.

The final variable is the duration of odour exposure. This ranges from study to study and is often not explicitly stated in method sections. Too short an exposure may produce non-significant results, yet too long an exposure may result in habituation and also produce non-significant results. The present study used approximately 20 minutes of exposure; however, this varied a small amount across individuals as some took longer to complete the tasks than others. From a practical viewpoint, aroma use in the office should be limited as advantageous effects may only be short-lived.

The present study has two major limitations. First, it is possible that a lemon aroma may hold different meanings for different people. It may have, in certain participants, acted as a cue to recall certain memories or to invoke positive or negative feelings, thus influencing cognitive task performance. Further study should take this into account, as it may produce bias within a

sample. Secondly, the present study used two laboratories. Other studies have used one laboratory and alternated 'aroma' and 'no aroma' days of experimenting. In the present study, participants left one laboratory and then walked a short distance to the other, and this activity may have interfered with the experimental effect of the aroma.

The present study was not fully intended to recreate a home or work environment: the many differences between home/work and a laboratory are apparent, and findings may not easily be generalised over different environmental contexts. The presence of ambient aroma (as opposed to other, more intrusive methods of odour delivery) has previously been used to represent a 'naturalistic setting'[14] and insofar as the present study used ambient aroma, it could be argued that it does the same. However, this is not a totally adequate argument, as experimentation still involves cognitive tasks and the use of laboratories. Experimenting in the home/workplace would be the most contextually valid method, yet this is both intrusive and was not practical in the present study. It is possible, therefore, that the presence of lemon aroma may still increase or maintain alertness when a person is not exposed to demanding and experimentally controlled mental tasks, as in the present study. This warrants further longitudinal research.

Future research could take several forms. First, it would be interesting to note whether changing variables such as duration of exposure or type of odour delivery would elicit the same effects of a lemon aroma as in the present study. Different concentrations of the same aroma could also be employed to see if results vary. Different concentrations of odour elicit different levels of activation in the cerebellum, with a higher concentration of odour resulting in greater activation. Malodours require further study and are relevant in examining sick building syndrome. Indeed, the health effects of odours have a strong biological basis in that the odour projection areas of the brain can directly alter immune status. These links are, however, bi-directional, meaning that the immune response can also affect the odour centres of the brain.

At an applied level, the present study extends our knowledge of how aroma may affect both hedonic tone and aspects of cognition. It also highlights methodological differences that make it hard to reach general conclusions from aroma studies. This study supports the claim that lemon is a 'pleasant odour' rather than a more specific 'pleasant relaxing' odour or 'pleasant alerting' one. Commercial air freshener producers and aromatherapists may, therefore, be misleading the public by claiming that lemon is uplifting and invigorating.

Lemon air products are widely advertised for the kitchen and bathroom and are said to 'revitalise', 'freshen' and 'stimulate'. The present study indicates this may not be true, but caution must be made in advocating this conclusion due to the limitations outlined above.

The presence of ambient lemon aroma may be practical for use in both an office and working/educational environment. The study supports the claim that office environments may become more productive, as shown by the increase in accuracy and speed of encoding new information. Increased hedonic tone may also prove beneficial when examining SBS. The lemon aroma may increase feelings of well-being and happiness, which may firstly make an office environment a more pleasurable experience; this may then lead to enhanced morale, which might decrease the symptomatology and prevalence of SBS.

## CONCLUSION

The effects of aromas on mood and cognition depend on aroma type, duration, the method of presenting the aroma, and the outcome measures used. The present study examined the effects of a lemon aroma presented using a commercial diffuser on a focused attention choice reaction time task, a categoric search choice reaction time task, and mood. Participants carried out one session with a lemon aroma and one with no aroma, the order of conditions being counterbalanced. The accuracy of identifying the presence of an aroma was at a chance level. Those in the aroma condition had higher hedonic tone scores both before and after carrying out the performance tests. Those in the aroma condition were more accurate but slower on the choice reaction time tasks. Exposure to the aroma also led to faster encoding of new information. Further research is now required to identify the mechanisms underlying these effects and to evaluate the practical relevance of them.

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