

# **Effects of Odorant Administration on Objective and Subjective Measures of Sleep Quality, Post-Sleep Mood and Alertness, and Cognitive Performance**

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The present study investigated whether odorant administration during sleep affects sleep patterns, mood, cognitive functioning, and alertness. Participants were monitored for 3 nights, during exposure to jasmine odor, lavender odor, and a non-odored condition. Following sleep, participants completed questionnaires related to mood and tests of cognitive functioning, and indicated alertness level throughout the day. Jasmine odor led to greater sleep efficiency and reduced sleep movement, without differences in total sleep time, thus providing increased sleep quality without the need for additional sleep time. Upon awakening, jasmine condition participants rated their level of anxiety and vigor lower, and performed the cognitive tests more rapidly. Level of alertness in the jasmine condition was greater than the control condition during afternoon hours. These findings provide support for odorant administration as an adjunct to improve sleep, alertness, and mental performance.

In the past 20 years, research concerning olfaction has dramatically escalated, with researchers trying to connect the workings of the olfactory system and psychological interpretation of odors with areas such as mood, behavior, and performance (for a review, see Gilbert, 1995; Lorig, 2001). Businesses have also taken advantage of research findings, and marketed products such as aroma therapy oils and candles, while others have pleasant odors (e.g., synthetic cookie or baking bread scents) diffused into their business venues in hopes of attracting and stimulating customers and sales.

Research on the more psychological and cognitive aspects of odor effects are compelling. Knasko (1992) noted that certain odors can influence mood and health. While undergoing a series of creativity and personality tests, 90 participants answered questions concerning their mood and perceived health. In one session the testing room was scented with either lemon, lavender, or dimethyl sulfide (a particularly unpleasant

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odor), while in another session the testing room was unscented. Fewer health symptoms were reported in the lemon condition and the presence of dimethyl sulfide resulted in the reporting of a less pleasant mood. Similar results were obtained by Knasko, Gilbert and Sabini (1990) when only the suggestion of an odor had been given to participants, without an actual odor being present. Rottman (1989) found that the presence of jasmine in a testing room enhanced performance accuracy of individuals on a cognitive task and lead to participants indicating more interest and motivation in the task. Lavender odor has been found to aid in the treatment of agitated behavior (Hensford, MacLaughlin, Wilkinson, Rosenvinge, Holmes, & Hopkins, 2002), leading to greater levels of relaxation, and has been found to reduce levels of mental stress (Yotsuya, Motomura, & Sakurai, 2001).

In the late 1980s, a series of research articles indicated that odors had widespread effects on the human central nervous system (Kobal & Hummel, 1988; Lorig & Schwartz, 1988; Van Toller, 1988), and that substantial changes in EEG activity occurred when odors were present. One explanation for the changes noted in EEG activity relates to attentional differences; EEG patterns change predictably when individuals actively attend to stimulus presentations. However, further research provided evidence that these EEG differences occurred even if the individuals were unaware that an odor was being administered (Lorig, Huffman, DeMartino & DeMarco, 1991). Thus, mere attention is not sufficient to alter such patterns.

Since odors have significant effects on behavior, cognitive performance, and the human nervous system, even in the absence of attention to and awareness of these odors, it is reasonable to suspect that the human body may respond to odors presented during sleep. Badia, Wesensten, Lammers, Culpepper and Harsh (1991) set out to test that hypothesis. These researchers assessed a variety of behavioral and physiological differences occurring in the presence of peppermint odor during stage 2 sleep. As opposed to the relaxing effects of jasmine and lavender odor, previous research on the effects of peppermint odor indicate that humans find it to be stimulating and arousing, with several studies noting that peppermint odor inhalation can improve alertness (Dember, Warm & Parasuraman, 1996; Jones, Ruhl, Warm & Dember, 1999; Warm, Dember & Parasuraman, 1991), vigor (Raudenbush, Meyer & Eppich, 2002), athletic performance (Raudenbush, Eppich, & Corley, 2001), and distract individuals from painful stimuli (Raudenbush, Koon, Meyer, Corley, & Flower, in press).

In their study, Badia et al. (1991) reported that their sleeping participants were able to indicate when the olfactory stimuli were being presented. In addition, during peppermint administration the percentage

of EEG speeding was greater, heart rate tended to be higher for the first part of the night, and there was an inhibitory effect on EMG activity. Given these findings, presentations of odors during sleep may also influence sleep quality, which could further impact post-sleep measures such as cognitive performance, alertness, and mood. Since a stimulating peppermint odor can arouse and alert sleeping participants, it is possible that a relaxing odor may have the opposite effects.

The effects of sleep loss on various aspects of performance are many and significant. Harrison and Horne (1999) note that sleep deprivation leads to more rigid thinking and increased errors in performing a cognitive task. Fairclough and Graham (1999) found a safety-critical decline in lane-keeping performance during two hours of simulated driving for individuals whose sleep allowance had been cut in half. A host of other researchers have also tied the effects of sleep deprivation with decreased verbal creativity (Randazzo, Muehlbach, Schweitzer & Walsh, 1998), poor school grades (Wolfson & Carskadon, 1998), poor cognitive task performance (Pilcher & Walters, 1997), and inability to process logical sequences of events (Heuer, Spijkers, Kiesswetter & Schmidtke, 1998). Furthermore, a meta-analysis of the effects of sleep deprivation on functioning, using data from 19 research studies, indicates that mood is profoundly affected by sleep deprivation, with sleep deprived individuals being more agitated, unhappy, and despondent (Pilcher & Huffcut, 1996). Given that some type of sleep deprivation (typically in the form of non-clinical insomnia) affects approximately one-third of the total population (Sharpley, Attenburrow & Cowen, 1997), and these problems are traditionally treated with drugs that are expensive and have deleterious side effects, any non-pharmaceutical adjunct to promote increased sleep quality should be greatly accepted.

The following study is designed to investigate whether the presence of a relaxing odorant during sleep has any effect on sleep patterns during the night, measures of mood and cognitive functioning the following morning, and alertness throughout the day. Participants will be monitored during sleep for three nights, during which they will be exposed to one of three conditions. These conditions consist of the presentation of one of two odorants (jasmine or lavender) or a non-odored control condition. The decision to use the scents of jasmine and lavender is based on research indicating these odorants result in individuals reporting greater relaxation, less anxiety, and increased mood (Knasko, 1992; Romine, Bush, & Geist, 1999; Rottman, 1989; Yagyu, 1994). During sleep, objective measures such as sleep latency, duration, movement, and efficiency will be measured. In addition, objective and subjective measures of cognitive performance and mood will be assessed following the night in the sleep laboratory, and level of alertness will be recorded

periodically throughout the next day.

Based on past research, it is expected that the presentation of the relaxing odors of jasmine and lavender would result in a general calming of the participant. If so, individuals should be able to fall asleep faster and have a more restful night of sleep. Given a more restful sleep, post-sleep measures of cognitive performance and mood should be higher in the odor conditions as compared to the control condition, and level of alertness should be enhanced throughout the day.

## METHOD

### Participants

Twenty participants (10 males, 10 females, mean age=19.8 yrs.) completed the study. For inclusion, participants first underwent a screening session, designed to eliminate those individuals indicating illicit drug use, prescription medication use, health problems, mood or mental disorders, allergies, olfactory sensitivity, anosmia, hyposmia, abnormal sleeping patterns, and/or sleeping pathology. Participants were college students, recruited through a flyer placed on campus, and compensated 75 dollars following the completion of the experiment.

### Stimuli and Odorant Conditions

Individuals participated for three sleep periods. These periods consisted of the presentation of jasmine odor, lavender odor, and a non-odored control condition. The odor conditions were maintained by aerating 15 ml of jasmine or lavender oil (Aldrich Co.) into tubing containing low-moderate flow (3 LPM) oxygen produced by an AirSep® Newlife Oxygen Concentrator. The oxygen concentrator is a portable device for producing variable oxygen flow on demand, which provides for greater control of oxygen flow rate than conventional oxygen tanks. In the non-odor control condition, only low-moderate flow oxygen was administered. The tubing was covertly positioned within the sleeping room and the scented or unadulterated oxygen diffused through the sleep room. Participants were not informed that odors were being presented.

### Sleep Room

The sleep room measured 2.75 m x 3.5 m and contained a standard single bed with box springs and mattress, nightstand table, and lamp. Bedding material consisted of a mattress cover, sheet, comforter, two pillows, and an additional blanket. The room was completely light-free when the door was closed and was maintained at  $21^{\circ}\text{C} \pm 1^{\circ}\text{C}$ .

### Sleep Measures

Measures of sleep quality and duration were recorded using a Mini

Mitter Actiwatch® Sleep Monitor. This device allowed for the recording of the following measures:

1. Sleep Efficiency: An index of the amount of time in bed that is actually spent sleeping, determined by dividing the actual sleep time by the time in bed and multiplying by 100.

2. Number of Minutes Spent Moving During Sleep: The period of time where movement occurs, between sleep start and sleep end, calculated by summing the number of epochs that are scored as mobile and multiplying that value by the epoch length in minutes. Epoch length was set at 0.25 minutes.

3. Movement Fragmentation Index: An index of restlessness, calculated by summing the "number of minutes spent moving percentage" with the "immobility phases of 1 minute percentage."

4. Sleep Time: The amount of time, between sleep start and sleep end that is scored as sleep. This is determined by summing the number of epochs that do not exceed the sensitivity threshold and multiplying that value by the epoch length in minutes. The sensitivity threshold was set at Mean Score in Active Period \* K divided by Epoch Length, where K is a constant (equal to 0.888), and epoch length is the sampling interval in minutes (equal to 0.25).

5. Sleep Latency: The period of time required for sleep onset after going to bed.

### Inventories

Participants completed the *Profile of Mood States* (POMS; McNair, Lorr & Droppleman, 1971). The POMS contains a list of 65 adjectives concerning current mood. Participants indicate the extent to which each adjective describes them at a particular moment using a 5 point scale. For the present investigation, questions were assessed within three pertinent sub-scales: fatigue, vigor, and anxiety.

Participants also completed the *Digit-Symbol Substitution Test* (DSST; McLeod, Griffiths, Bigelow & Yingling, 1982). The DSST is a measure of both cognitive information processing speed and psychomotor performance. Participants must match a series of symbols and digits, and a faster completion time is indicative of greater cognitive processing and psychomotor performance. Different versions of the test were used for each condition to minimize practice effects.

### Procedure

After initial screening and acceptance for the study, participants were instructed as to the procedures of the experiment and reported to the laboratory prior to 11:45 pm of each testing date (the actual arrival time varied for each participant). As part of the screening protocol and

scheduling of nights in the laboratory, the researchers ensured that the participants did not have any atypical events for the following day that might interfere with their normal sleep (i.e., examinations, early morning class or work commitments, presentations, etc.).

Participants performed the protocol three times, each time under a different odor condition (jasmine odor, lavender odor, non-odor control condition), separated by a minimum of two days and a maximum of seven days. The order of the conditions was randomly assigned. While there is some concern among investigators that a "first night effect" (i.e., sleeping in a novel environment) may lead to variations in recordings made the first night of sleep studies (Agnew, Webb, & Williams, 1966), such an effect is unlikely to have a significant impact in the present study. Participants were sleeping in University testing rooms, which housed accommodations and bedding equivalent to their own University dormitory rooms. In addition, there were no invasive measures, externally applied electrode leads, or external personal observation of them while sleeping, which have been shown to produce much of the variability due to the "first night effect" (Browman & Cartwright, 1980; Coble, McPartland, Silva, & Kupfer, 1974).

Participants were placed in the sleep room prior to midnight, and were instructed to leave the sleep room (which opened into a secure general testing area) when they were ready to begin their day, at which point the morning testing would begin. Sleep-wear was at the discretion of the participants, and alarm clocks were not allowed.

Upon awakening, participants first completed the *Digit-Symbol Substitution Test* (McLeod, Griffiths, Bigelow & Yingling, 1982). Participants were instructed that they should complete the task as quickly as possible (since they would be timed), but also as accurately as possible. They then completed the *Profile of Mood States* (McNair, Lorr & Droppleman, 1971).

Throughout the day, participants were prompted to enter their level of alertness using the Actiwatch<sup>®</sup>, which prompted them via a tone to make their ratings at 10:00am, 12:00pm, 2:00pm, and 4:00pm ( $\pm 10$  min). The tone was of sufficient volume to alert the participants to respond. Ratings were made on a 1-10 scale, where 1 indicates not alert and 10 indicates completely alert. Participants returned the ActiWatch<sup>®</sup> at some point after their 4:00pm alertness rating, during which time their data were loaded into the analysis software.

## RESULTS

Unless otherwise noted, the variables were subjected to a repeated measures ANOVA, with Tukey HSD post-hoc contrasts when indicated. See Table 1 for means and standard errors for the test variables among

the odorant conditions.

### Objective Sleep Measures

A significant effect was found for sleep efficiency,  $F_{(2,36)}=5.99$ ,  $p<.01$ . Sleep efficiency in the jasmine condition was greater than both the control and lavender conditions.

A significant effect was found for the total number of minutes spent moving during sleep,  $F_{(2,36)}=7.34$ ,  $p<.01$ . Participants spent fewer minutes moving in the jasmine condition than both the control and lavender conditions. The *Movement Fragmentation Index* among the odorant conditions was also significant,  $F_{(2,36)}=4.24$ ,  $p<.05$ . The jasmine condition score was lower than the control condition.

No differences were found for total sleep time or sleep latency,  $F_{(2,36)}=.50$  and 1.41, respectively,  $p>.05$ .

TABLE 1 Means and Standard Errors for the Measures Among the Odor Conditions

MEASURE	CONTROL	JASMINE	LAVENDER
Sleep Efficiency	90.46 (0.90)	93.40 (0.62)	90.73 (0.90)
D-S Subs. Test (sec)	75.02 (2.59)	67.69 (2.38)	69.79 (2.66)
Total Sleep Time (min)	464.96 (7.12)	464.42 (12.61)	454.26 (10.95)
Sleep Latency (min)	24.70 (2.74)	26.69 (2.42)	29.11 (2.76)
Total Minutes Moving	27.57 (1.58)	20.92 (1.90)	25.97 (1.84)
M F Index	9.45 (0.55)	7.17 (0.80)	8.51 (0.82)
POMS Anxiety (mean)	4.75 (0.41)	2.85 (0.80)	4.55 (0.68)
POMS Vigor (mean)	15.30 (1.21)	12.65 (1.26)	11.25 (1.28)
POMS Fatigue (mean)	4.90 (0.76)	3.90 (0.95)	5.65 (0.81)

### Cognitive Performance

A significant effect was found for the amount of time required of the participants to complete the Digit-Symbol Substitution Test,  $F_{(2,38)}=3.45$ ,  $p<.05$ . The test was completed more quickly after sleeping in the jasmine condition than the control condition.

### Mood

A significant effect was found for the POMS anxiety sub-scale,  $F_{(2,38)}=3.73$ ,  $p<.05$ . Level of anxiety in the jasmine condition was less than both the lavender and control conditions.

A significant effect was found for the POMS vigor sub-scale,  $F_{(2,38)}=4.93$ ,  $p<.05$ . Level of vigor in both the jasmine and lavender conditions was less than the control condition.

No differences were found among the conditions for the POMS fatigue sub-scale,  $F_{(2,38)}=1.61, p>.05$ .

### Alertness

The alertness scores were subjected to a two-within (odor condition and scores over time throughout the day) ANOVA. No significant effect was found for odor condition,  $F_{(2,36)}=2.20, p>.05$ . A significant effect was found for scores over time throughout the day,  $F_{(3,54)}=3.87, p<.05$ . In general, there was an increase in alertness from the first recording of the day (10:00am) to the second (12:00pm). Finally, there was a significant interaction between odor condition and scores over time throughout the day,  $F_{(6,108)}=2.24, p<.05$ . Those who slept in the control condition showed a decline in alertness during the second half of the day, while those who slept in the jasmine condition showed an increase in alertness during the second half of the day (see Figure 1).

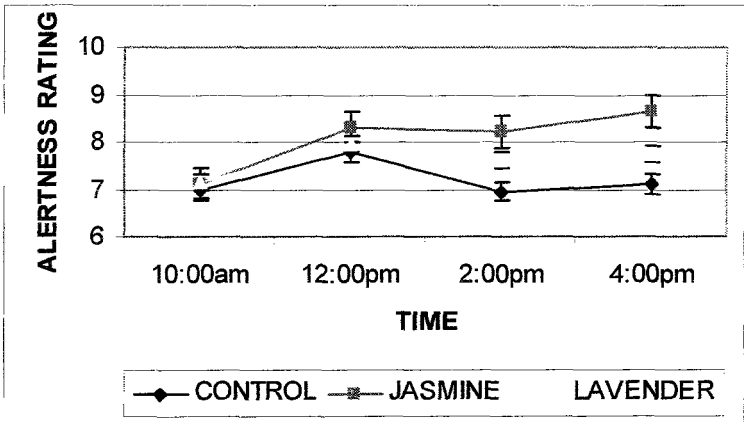


FIGURE 1 Interaction of odor condition and alertness scores over time.

### DISCUSSION

The present study investigated whether the administration of an odorant during sleep affects sleep patterns during the night, cognitive functioning and mood the following morning, and alertness throughout the day. Some type of sleep deprivation (typically in the form of non-clinical insomnia) affects approximately one-third of the total population (Sharpley, Attenburrow & Cowen, 1997). Thus, in an age when a poor night of sleep is frequently reported, which may have further implications on mood, cognitive functioning, and alertness throughout the next day, it



is important to assess non-pharmacological adjunct techniques that might help assure a good night's rest.

In comparison to the non-odor control condition, jasmine odor administration led to greater sleep efficiency and reduced sleep movement, although there was no difference in the total amount of sleep. Thus, participants were experiencing an increase in sleep quality, without the need for additional sleep time. Past research has indicated that odors have widespread effects on the human central nervous system (Kobal & Hummel, 1988; Lorig & Schwartz, 1988; Van Toller, 1988; Yagyu, 1994), even when the participant is unaware that an odor is being administered (Lorig, Huffman, DeMartino & DeMarco, 1991). Further, Badia, Wesensten, Lammers, Culpepper, and Harsh (1991) found that the human body can respond to odors presented during sleep. The present findings provide additional support that an odor presented during sleep can have marked effects on sleep behavior. Future studies should address specific EEG/EOG/EMG activity accompanying odorant administration.

While lavender odor was successful at elevating mood, no other lavender effects were found, despite both jasmine and lavender sharing several of the same psychophysical (intensity, pleasantness) and psychological (relaxing) properties. Future research should address the specificity of particular odorants to produce the same effects as those noted in the present study. It is unlikely that jasmine is the only odorant which will modulate the sleep response, and, in fact, certain odors (particularly those which are hedonically unpleasant) may actually interfere with a person's ability to have a restful night of sleep.

Upon awakening, participants in the jasmine condition rated their level of anxiety and vigor lower, and performed the cognitive test more rapidly. Rottman (1989) also found that jasmine odor enhances cognitive task performance, in addition to increasing interest and motivation in such tasks. Students may find this outcome particularly helpful, as they are frequently required to engage in mentally demanding tasks throughout the day. Athletes, as well, may benefit from a jasmine scented bedroom. Savis, Eliot, Gansneder, and Rotella (1997) report that athletes have a significant decrease in hours of sleep one and two nights before competition, due to being excited, eager, or anxious. Sleeping in a jasmine scented room may help to alleviate some of an athlete's anxiety before a competition. However, it should be noted that vigor levels were lower in the morning (most likely a consequence of increased relaxation and reduction in anxiety), and that level of alertness in the jasmine condition was not greater than the control condition until the afternoon hours. Thus, athletes should be cautious of utilizing this technique with early morning competitions.

More generally, however, there are numerous occupations where a

poor night's sleep could have potentially disastrous effects, such as physician, air traffic controller, pilot, and long-haul driver. For example, driving over long periods of time has produced visual tracking and driving speed variations of the same magnitude as 0.08 blood alcohol concentration (Arnedt, Wilde, Munt, & McLean, 2001; Lenne, Triggs, & Redman, 1998) and a safety-critical decline in lane-keeping performance (Fairclough & Graham, 1999). A Gallup poll conducted for the National Sleep Foundation reported that 31% of adults said they had fallen asleep at the wheel. Such detrimental effects are even more pronounced for those individuals whose profession is driving, with research showing that one out of four truck drivers' self-ratings of fatigue are in the "tired" range, with 24% of such drivers failing a simple psychomotor performance test (Charlton & Bass, 2001). In the year 2000, there were 5,362 truck-driver related fatalities, with approximately 800 of those fatalities being related to driver fatigue. The ability to produce a more rested driver should be of interest to automobile manufacturers, departments of transportation, long-haul trucking firms, and insurance companies.

Further extensions may also serve an important function within a hospital setting, in the hope of minimizing the stress associated with hospital stays, while at the same time providing the patient with restful sleep. In addition, while the present study was performed using participants from a non-clinical sample, the potential to improve quality of sleep in sleep-disordered individuals is indicated.

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