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RESEARCH ARTICLE

The Influence of Scent on Sleep Quality

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ABSTRACT

The use of scents in sleep medicine is gaining increasing attention since they have been shown to improve sleep quality. This randomized double-blinded crossover trial measured the extent to which a continuous nightly presentation of a synthetic jasmine scent combined with lavender oil and passionflower herb improves subjective and objective sleep quality. Thirty sensitive sleepers (ISI 7-14) who suffer from delayed sleep-onset and frequent sleep disturbances (2-3 per week) were monitored under four conditions in the sleep laboratory over four nights. The first night was for acclimation (baseline), and the other nights were randomized in a counterbalanced order (placebo rose scent, a high-dose of jasmine scent, or a low-dose relative to the essential oils). Alongside this, subjects were given standardized questionnaires to complete in the morning and evening. There was a significant improvement in sleep quality and total sleep time when using scents compared to baseline. Furthermore, both variants of jasmine decreased wake after sleep onset. The results also indicated that the application of scent on the T-shirt was well tolerated by all subjects. Overall, it was shown that the jasmine scent may positively affect sleep parameters, and moderators such as dosage, application method, and duration of the scent should be further investigated.

Introduction

A poor night of sleep can influence a range of negative health consequences including daytime sleepiness, neurocognitive impairment, and ill-health [1-3]. Therefore, it is crucial to get a good night of sleep in order to maintain a healthy lifestyle. One method in which we can try to enhance sleep quality is by optimizing numerous sensory influences in the sleep environment such as comfort, humidity, avoidance of light, noise, and uncomfortable temperature [4-7]. So far, little research has been conducted on the influence of scents on sleep. However, the use of essential oils in medicine to treat anxiety, pain, and sleep disorders is increasing. A review by Wang and Heinbockel investigated the effects and mode of action of oils from plants and their constituents. They found a promising influence on the GABAergic system and a mechanism of action similar to that of benzodiazepines. However, not all pathomechanisms have been clarified [8].

There are very few studies that use scents in relation to sleep quality, one study aimed to help cancer patients with sleep disorders using olfactory pens and/or a special kind of inhaler. Both the pen and the inhaler used a mix of essential oils and scents. The results showed that after 13 weeks, 64% of subjects reported at least one point improvement on a Likert scale [9]. Another study used lavender oil to improve sleep quality and they reported an increase in the percentage of deep sleep in young people. In addition, lavender oil was found to reduce Wake After Sleep Onset (WASO) in females [10]. A similar protocol was conducted with young adults and a peppermint scent. The effect differed depending on the individual perception of the scent. When it was perceived as very intense, it prolonged sleep duration and the proportion of deep sleep [11]. This suggests that the best-known sleep-promoting scent is lavender.

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Recently, a new scent has been developed known as Vertacetal Coeur (VC). This is a synthetic jasmine scent and it has been shown to have a sedative effect [12]. The scent contains 1,3 dioxanes which are known to potentiate GABA-induced inhibitory channel currents. This has already been demonstrated in mice who displayed significantly reduced physical activity following administration of the 1,3 dioxanes. These derivatives are a class of compounds that act on GABA receptors and enhance GABA responses. Thus, this scent acts on the same receptors as benzodiazepines, valerian, chamomile, lemon balm, and other herbs [12].

In the present study, VC was tested in combination with lavender oil and passionflower herb. The lavender oil (Lavendula Angustifolia) is supposed to have an additional calming effect and the passionflower herb (Passiflora incarnata) should produce an anti-anxiety effect.

The aim of the study is to investigate the influence of the synthetic jasmine scent on subjective and objective sleep quality and daytime well-being in sensitive sleepers. In addition, the feasibility and tolerance of the application on a sleep shirt will be assessed. As mentioned earlier, previous research has used equipment such as olfactometers and different variants of inhalers in patients with cancer, depression, and other comorbidities. However, this has not been investigated in non-healthy subjects with mild insomnia and without known comorbidity (sensitive sleepers).

Methods

Subjects

Thirty adults (fifteen female; aged 35–63 years; mean age 47 ± 8 years) were monitored in a sleep laboratory over four consecutive nights. Subjects were recruited through either a database, online advertisements, or ongoing sleep consultations. Those included met the following criteria: 1) occasional difficulty falling asleep and staying asleep; 2) less than three sleep problems per week [ICDS-3], and 3) an index of Insomnia Severity (ISI) between 7 and 14 (mild insomnia). The exclusion criteria used the following: 1) any known sleep disorders other than insomnia; 2) use of hypnotics; 3) medications, drugs, or alcohol that affect the sleep-wake cycle; 4) shift work; and 5) acute or chronic diseases that affect sleep. Ethical approval was obtained from the Charité - Universitätsmedizin Berlin [EA 1/103/20].

Sleep recording

Polysomnography (PSG) was performed using the Embla N7000 system (Embla Systems, Thornton/CO, USA) to objectively assess sleep quality. The standard measurements electroencephalogram, electrocardiogram, electromyogram, and electrooculogram were recorded and evaluated according to the criteria of the American Academy of Sleep Medicine (AASM). The sleep parameters extracted from the recordings were Sleep Onset Latency (SOL) – the time it takes to fall asleep, Total Sleep Time (TST), WASO – the number of awakenings during the night, and Latency to Persistent Sleep (LPS) – the time it takes from lying down to falling and remaining asleep for at least 10 minutes.

Questionnaires

Subjects completed the German versions of the Sleep Questionnaire A (SF - A), Current Mood State (ASTS), Karolinska Sleepiness Scale (KSS) in the morning and evening of each day throughout the trial. Also, the opinion on the scent was asked each morning. These were used to record subjective sleep quality, mood, sleepiness, and perception of the scent, respectively.

Scent

Each scent was provided in liquid form by the company M'Arome GmbH. A rose scent with low-dose phenylethyl alcohol (33%) was used as the placebo. The scent under investigation was a mixture consisting of VC combined with essential oils and essences (50% lavender oil and 50% passionflower herb). Two variants were tested, variant A (90% VC, 10% essential oils) and variant B (40% VC, 60% essential oils). In each case, 1 ml of the scent was applied to a cellulose pad (10 x 10 cm) and was fixed to the T-shirt in the chest area. Therefore, permanent inhalation of the scent was possible despite possible changes in position.

Procedure

In this randomized double-blinded crossover design, subjects slept in the sleep laboratory over four consecutive nights. There was a baseline night for acclimatization followed by three nights under the influence of either the placebo scent, variant A or variant B. The order in which the scent was given on these three nights was randomized and counterbalanced. During the day, subjects followed their normal routines and at night, standard sleep laboratory conditions were kept constant such as, room temperature staying between 18 - 22°C and little to no noise.

Data analysis

The polysomnographic data were scored visually according to AASM criteria by a certified somnologist using RemLogic software (Embla Systems, Thornton/CO, USA) and all analyses were performed using SPSS (version 23.0. Armonk, NY) and MATLAB 2021a (The MathWorks, Natick, MA). A $p < 0.05$ was considered statistically significant. Basic analytical approaches were used to analyze questionnaires, these included a non-parametric test for ordinal ratings, and Chi^2 tests for nominal ratings, respectively. A repeated measures Analysis of Variance (rmANOVA) was used to investigate the effect of scent in polysomnographic data and the Greenhouse-Geisser correction was applied to p values in case of violated sphericity assumption (Mauchly test $p < .05$). Effect sizes were reported by eta squared.

Results

Polysomnography

The results from the one-way rmANOVAs for the condition factor (baseline *vs.* placebo vs. variant A *vs.* variant B) showed consistently better outcomes for the application of scents (placebo, variant A, variant B) as compared to the baseline night without scent application (TST: $F_{GG}(2.29, 66.51) = 5.66$, $p < .01$, $\eta^2_{GG} = .16$, SOL: $F_{GG}(2.22, 64.39) = .97$, $p = .413$, $\eta^2_{GG} = .03$, LPS: $F_{GG}(1.95, 52.58) = 5.25$, $p < .01$, $\eta^2_{GG} = .16$, WASO: $F(3, 87) = 3.83$, $p < .05$, $\eta^2 = .12$). However, the comparison between PSG parameters of the three scents showed no significant difference between these three groups, except for WASO. Here, both variants of jasmine showed significantly lower scores compared to the baseline and the Placebo condition. Figure 1 shows the duration (in min.) of each PSG parameter (y-axis) as a function of all four conditions (x-axis).

Karolinska Sleepiness Scale

One item of the KSS has been used to measure subjective sleepiness: "How sleepy do you feel at this moment?" which was answered after each night. The Friedman test (non-parametric test for ordinal ratings) was used to detect differences across multiple measurements: The subjects' sleepiness did not differ significantly between groups ($X^2(3, N = 30) = 5.24$, $p > .05$). However, subjects rated the highest sleepiness score after the baseline night. All three scents (placebo, variant A, and variant B) had comparable effects on perceived sleepiness, as indicated by their similar medians. Figure 2 shows a box plot that demonstrates the distribution of responses for all four conditions.

Current mood and Sleep questionnaire A

There were no significant differences for positive mood ratings in the ASTS when comparing the prior evening with the morning after a night with any of the scents (placebo: 2 ± 5.4; $p = .05$; variant A: 1.6 ± 6.1; $p = .17$; variant B: 0 ± 5.5; $p = .97$). Furthermore, there were also no significant differences between the three applied scents with regard to sleep quality in SF-A ratings (placebo: -0.1 ± 0.9; $p = .53$; variant A: -0.2 ± 0.8; $p = .1$; variant B: -0.2 ± 0.8; $p = .13$).

Adherence

After each night, subjects rated their impression of the various scents (placebo, variant A, variant B) by answering "yes/no" questions. In terms of adherence, Variant B had a smaller advantage. Over 50% of the subjects would reuse any scent and 60% of those would prefer to use variant B again.

Perception of scent and safety

Additionally, the Friedmann tests indicated no significant differences between intensity ratings of all three groups ("pleasant": $X^2_F(2) = 1.93$, $p = .6$, "intrusive": $X^2_F(2) = .92$, $p = .63$, "intensive": $X^2_F(2) = 2.08$, $p = 3.52$) (Figure 3). All scents caused a headache in 7% placebo, variant B) – 8% (variant A) of the respondents while none of the subjects experienced nausea.

Discussion

Our study demonstrated that the separate use of a synthetic jasmine scent and a rose scent could improve objective sleep quality in subjects with mild insomnia and/ or mild sleep disturbances. However, both variants of the synthetic jasmine showed the greatest improvement in WASO compared to placebo and baseline. Alongside this, subjective reports of each scent were perceived to be similar to one another and were well tolerated. These findings suggest that any of the scents used in this research may be beneficial to those with mild insomnia and/ or sleep disturbances as they improve sleep quality and were well tolerated. It should be noted that our study involved only a small study population (pilot study) and that only the acute effect was tested.

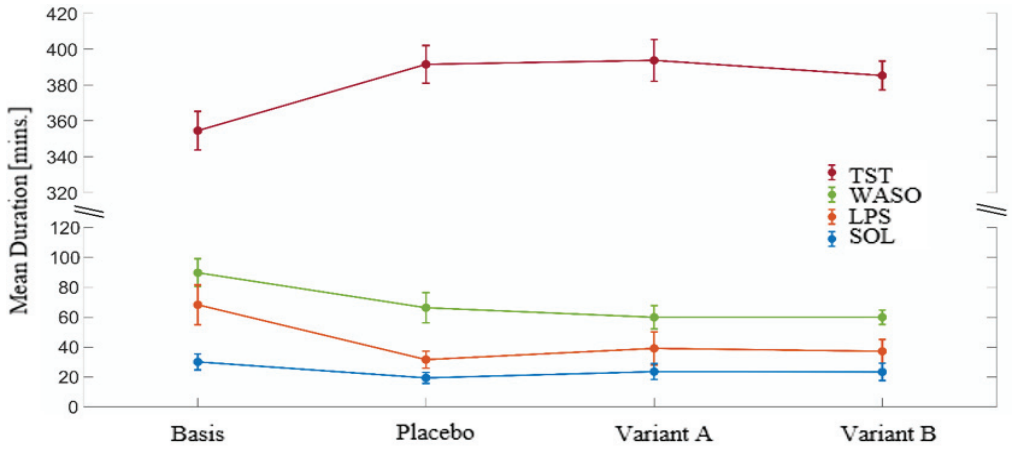

Figure 1 A line graph to display the mean and standard deviation of duration (minutes) for each objective sleep parameter. Note the leap on the y-axis due to different ranges of measured parameters.

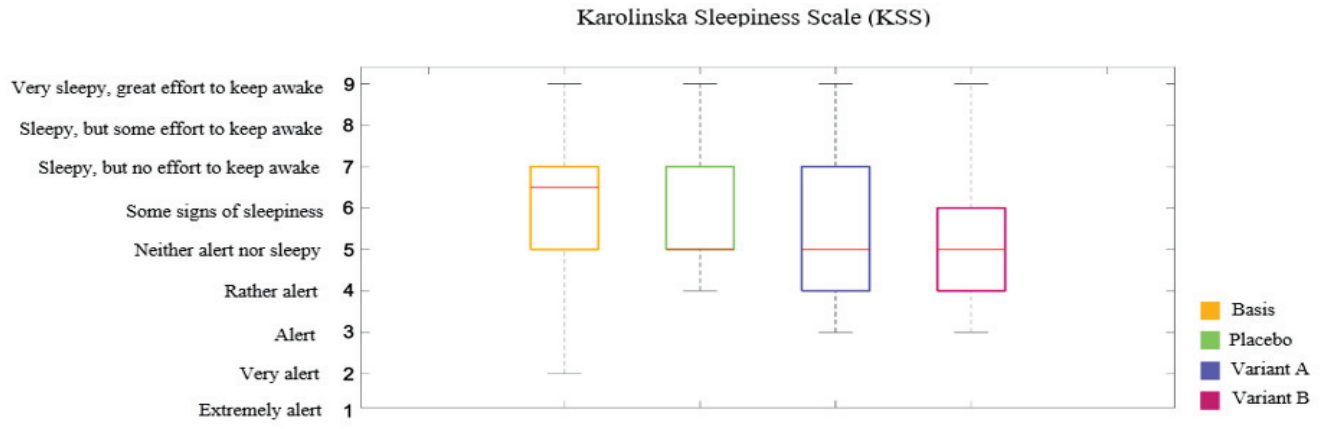

Figure 2 A box plot to display the subjective sleepiness ratings from one question from the KSS regarding all four conditions (color-coded; see legend) with answer options coded on a Likert scale (higher values on the y-Axis indicate stronger sleepiness). The red horizontal line represents the median, lower and upper box edges code the .25 and .75 quartile, respectively. Dotted lines indicate the response range.

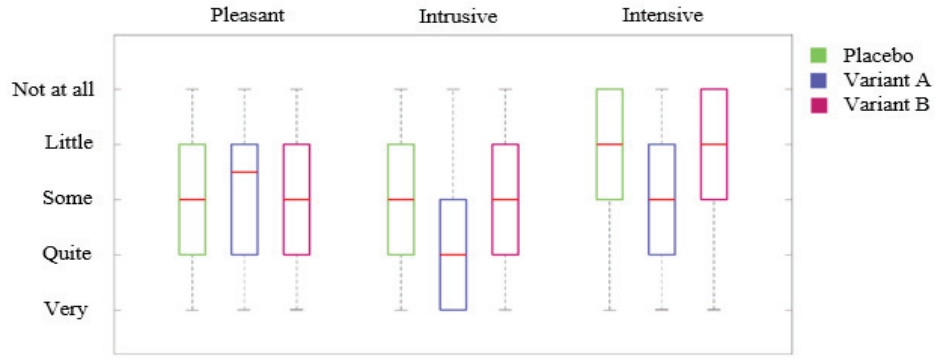

Figure 3 A box plot to display the perception of scent for placebo, variant A, and variant B. All three conditions are color-coded; see legend and the answer options are coded on a Likert scale from 1 ("very") to 5 ("not at all"). The red horizontal line represents the median, lower and upper box edges code the .25 and .75 quartile, respectively. Dotted lines indicate the response range.

When we view each scent individually, there was no clear significant difference between them for improving objective sleep quality. This would suggest that all three of these scents were equally as effective. However, the high dose of synthetic jasmine accompanied with an essential oil mixture showed the most improvement within each sleep parameter, even if it was minimal. On the other hand, if we consider the feasibility of the application and the opinion of the subjects, over half of them would reuse any of these scents and 60% of those would reuse the low dose of jasmine, which they rated as very pleasant and not very intrusive. Therefore, variant A would be best for optimizing sleep quality. However, for the sake of a few minutes, it would make more sense to promote variant B as it works just as well and is perceived more positively.

This current research is novel as it uses a synthetic jasmine scent that has not been tested in humans to improve sleep quality. Prior to this, it has only been investigated in mice [12]. However, the influence of naturally grown jasmine has been tested previously in this setting [13]. The results indicated that jasmine has a positive improvement on objective and subjective sleep quality – which is in line with our results - however, it is difficult to directly compare this with our results as the effect comes from plant-based constituents which are not necessarily transferable to synthetic effects.

The placebo scent consisting of a rose aroma with low-dose phenylethyl alcohol (33%) may have had its own positive effect on sleep quality, which was unexpected. It showed similar results compared with both synthetic jasmine scents when improving sleep quality. Research conducted by Vitinius, et al. [14]. showed the potential positive effects of a rose aroma. They showed that depressed women felt well recovered after a night with a rose scent compared to a night without [14]. On the other hand, it is possible that this was a placebo effect. A recent study investigated the placebo effect in patients with sleep disorders; they received either a placebo sleep agent or no "drug" for one week. Half of the subjects who received the sleep agent were informed that there might be some side effects such as increased or decreased appetite. Not only did the sleep quality of the subjects who were not informed of side effects become significantly better, but also

the subjects with advanced warning were also significantly more likely to notice the suggested side effects [15]. Similar results were also shown in Fratello's research using placebo pills to improve sleep parameters. They demonstrated that WASO and the number of awakenings were significantly reduced in students with sleep problems [16]. Either of the reasons are equally possible, the rose scent may have some sleep quality improving effects or it could be a placebo effect. Nonetheless, it provided a positive impact on sleep quality.

The mode of application should also be noted. The application of scent to a T-shirt at chest level was very feasible and well tolerated by all subjects. In the domestic environment, the application would be easy to carry out. Repeated nightly administration may provide a better effect than the single application which was performed in this study. However, there is not yet sufficient literature on different application times for scents. For instance, there are only a few studies in which the scent was applied throughout the night. They were delivered in various forms inhalers, olfactometers, cotton balls, or vials before bedtime or during a specific rhythm during sleep (Table 1). These results use different modes of application which reduces the comparability of this study.

The location of application of the scent could also play a role. In this study, it was applied at chest level, similar to Hamzeh et al [17]. A singular or continuous application by dripping onto a T-shirt arguably represents a simpler and less expensive delivery of the product than through, for example, inhalers that emit the scent upon inhalation [14,18,19].

The general advantage of a scent over tablets is the image and adherence to the measure. It is known that reduction of tablets increases adherence to regular and prescribed intake of oral medications [20].

The initial positive results from this study should be confirmed or modified by further long-term applications. In our study, subjects did sleep under standardized conditions which is beneficial for comparative assessment of effects on sleep. However, a similar protocol under home conditions could presumably have a more positive effect on sleep quality, as people sleep better in the home environment than in the sleep laboratory [21]. The length of use may also play a role. When phytopharmaceuticals are used as a sleep-promoting product they usually only have a small effect and it may take a bit of time to receive the full benefits. Valerian, for example, takes approximately 2-3 weeks before a sleep-promoting effect occurs [22]. Since our study was only one night with the respective scent, a further decrease in WASO and improvement of other sleep parameters is quite possible if they were applied for a longer period.

Conclusion

For the first time, a positive effect was demonstrated

Table 1: Comparison of different studies that successfully demonstrated the use of fragrances in relation to sleep quality (PSG: Polysomnography; SSS: Standford Sleepiness Scale; POMS: Profile of Mood States Questionnaire; SF: A u. B - Sleep Questionnaire A u. B).

Author	N (N Gender)	Age	Length of Study	Method of Application	Duration of the Application	Measures	Subjects	Scent
[9]	65 (54 F, 11 M)	52 (16 - 84)	13 weeks	Smell pen (type inhaler)	Inhaled approximately 4-5 times, as often as the patient wished	Likert scale	Cancer patients	Bergamot and sandalwood or incense, mandarin, and lavender or a mixture of 7 fragrances (subject's choice).
[10]	31 (15 F, 16 M)	20 ± 2	3 days	Vial at chest level	Between 23.10 - 23.40 every 10 min for 2 min	PSG, SSS, POMS	Healthy sleepers	Lavender oil or distilled water
[11]	21 (11F, 10 M)	20 ± 2	3 days	Vial at chest level	Between 23.10 - 23.40 every 10 min for 2 min	PSG, SSS, POMS, Likert Scale	Healthy sleepers	Peppermint or distilled water
[13]	20 (10F, 10 M)	19,8	3 days	Oxygen diffuser with 15 ml of the scent	3 l of oxygen per minute (3 LPM) during sleep	Mini Mitter Actiwatch Sleep Monitor, POMS, Digit Symbol Substitution Test	Healthy sleepers	Jasmine, lavender, or oxygen only (placebo)
[17]	120 (68 F, 52 M)	49 ± 15	7 days	Cotton balls on the collar	21:00 which was 20 minutes prior to bed	PSQI (Pittsburgh Sleep Quality Inventory)	Cancer patients	Lavender or peppermint
[18]	40 (35 F, 5 M)	41 ± 9	10 days	Olfactometer (scent via nose clip or nasal tube)	After falling asleep, every 30 seconds during 6 hour	SF - A and actigraphy/motion sensors	PTSD - patients	Rose, lavender, orange, or peach (subject choice) or none (placebo).
[19]	34 (19 F, 15 M)	27 ± 3	day	Olfactometer (nose mask)	20 minutes after the onset of the N2 phase, then about 30 times administration for 5, 10, or 20 seconds according to a computer algorithm	PSG	Healthy sleepers	Lavender, vanilla, vetiver, or ammonium sulfide
[14]	27 (F)	32 ± 7	3 days	nasal cannula, connected with a breathing device	After falling asleep, every 2 minutes	SF - A and B, MMQ (multidimensional mood questionnaire)	Patients with mild to severe depression	Rose or air (placebo)

using a synthetic jasmine scent on sleep quality. Furthermore, the application of the scent to a T-shirt during sleep was feasible and well tolerated by the test subjects. This means that scent therapy has the potential to be part of a stepwise therapy such as cognitive behavioral therapy to improve mild insomniac complaints. However, moderators such as dosage, application method, and duration of the scent should be further investigated.

Acknowledgment/Conflict of Interest

We thank the team of ASR (Advanced Sleep Research GmbH, Berlin) for taking care of the subjects.

The corresponding author declares no conflict of interest for himself and his co-authors.

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