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The Influence of Essential Oils on Human Attention. I: Alertness

Josef Ilmberger, Eva Heuberger[1], Claudia Mahrhofer[1], Heidrun Dessovic[1], Dietlinde Kowarik[1] and Gerhard Buchbauer[1]

Department of Physical Medicine and Rehabilitation, Klinikum Grosshadern,
Ludwig-Maximilians-Universität, Marchioninistrasse 15, D-81377 Munich, Germany and
[1]Institute of Pharmaceutical Chemistry, Center of Pharmacy, University of Vienna,
Althanstrasse 14, A-1090 Vienna, Austria

Correspondence to be sent to: Dr Josef Ilmberger, Department of Physical Medicine and Rehabilitation, Klinikum Grosshadern, Ludwig-Maximilians-Universität, Marchioninistrasse 15, D-81377 Munich, Germany

Abstract

Scientific research on the effects of essential oils on human behavior lags behind the promises made by popular aromatherapy. Nearly all aspects of human behavior are closely linked to processes of attention, the basic level being that of alertness, which ranges from sleep to wakefulness. In our study we measured the influence of essential oils and components of essential oils [peppermint, jasmine, ylang-ylang, 1,8-cineole (in two different dosages) and menthol] on this core attentional function, which can be experimentally defined as speed of information processing. Substances were administered by inhalation; levels of alertness were assessed by measuring motor and reaction times in a reaction time paradigm. The performances of the six experimental groups receiving substances ($n = 20$ in four groups, $n = 30$ in two groups) were compared with those of corresponding control groups receiving water. Between-group analysis, i.e. comparisons between experimental groups and their respective control groups, mainly did not reach statistical significance. However, within-group analysis showed complex correlations between subjective evaluations of substances and objective performance, indicating that effects of essentials oils or their components on basic forms of attentional behavior are mainly psychological.

Introduction

During the last decade, the topic of aromatherapy has been of increasing interest to the general public. Publications in this area describe fragrances to be a powerful means of reducing subjectively experienced stress and workload, and aromatherapy today is used mainly for relaxation or improvement in personal efficiency. Scientific investigation of the effects of essential oils on behavior clearly lags behind this popular trend and the results are far from being consistent.

To date, activating and sedative effects, which are attributed to many of these substances, have been demonstrated mainly in animal research. Kovar *et al.* (Kovar *et al.*, 1987) showed that rosemary oil has a stimulatory effect: the locomotor activity of mice was increased significantly after inhalation as well as after oral administration of the substance. The authors also found that the increase in locomotor activity corresponded well with the blood concentration of 1,8-cineole, the main constituent of the oil. In a similar experiment, Buchbauer *et al.* (Buchbauer *et al.*, 1993) demonstrated stimulatory and sedative effects after inhalation for more than 40 essential oils and fragrance compounds which had been described as sedative in the literature. The effects of the substances on the locomotor activity of mice were tested under normal conditions as well as after pretreatment with caffeine. Lavender and neroli oil as well as linalool, linalyl acetate and citronellal were the most effective sedatives and significantly reduced locomotor activity in both experimental conditions. On the other hand, orange terpenes, isoborneol and isoeugenol significantly increased the motility of the animals under normal conditions, whereas after caffeine pretreatment the same fragrances clearly decreased it; thus for these substances there is a clear interaction between level of activity and treatment.

In the human domain, research in the assessment of stimulatory and sedative properties of fragrances can be divided roughly into two fields: investigation of electrophysiological parameters on the one hand and of behavioral effects on the other hand. In an electrophysiological study, Torii *et al.* (Torii *et al.*, 1988) suggested that these effects can be determined by odor-induced alterations in contingent negative variation (CNV). In their experiments, subjects were exposed to an auditory stimulus followed by a visual stimulus. Subjects were asked to turn off the light as quickly as possible by pressing a button. One to three seconds before the sound stimulus appeared, subjects inhaled an essential oil from an impregnated filter-paper. Filter-papers impregnated with fatty oils served as blanks. Changes in the subjects' CNV magnitude after presentation of the odor as compared with the blank indicated whether the odor had stimulatory or sedative effects on the brain. Twenty different essential oils were tested by this procedure; for most of them changes in the magnitude of CNV corresponded with the effects attributed to them in aromatherapy. For example, jasmine, which is said to have stimulatory properties, significantly increased the magnitude of CNV, while lavender, which is thought to be sedative, led to a significant decrease in the magnitude of CNV.

The value of CNV as an indicator of the stimulatory and sedative properties of essential oils was seriously questioned by Lorig and Roberts (Lorig and Roberts, 1990), who replicated the study of Torii and coworkers and introduced an additional odor condition. As in the experiments of Torii *et al.*, changes in CNV after the inhalation of jasmine and lavender were measured. Responses to a mixture of the two fragrances were also recorded. Subjects were led to believe that they would be exposed to high and low concentrations of the odors. In the 'high concentration' conditions, pure fragrances were administered, while in the 'low concentration' conditions, the mixture was used. For the 'high concentration' conditions, the findings of Torii *et al.* were confirmed. However, in the 'low concentration' conditions, changes in CNV reflected the expectation of the subjects, indicating that expectations concerning an odor may crucially influence the effect of that odor on the CNV.

Evidence for the effects of fragrances on behavior has been supplied by Warm *et al.* (Warm *et al.*, 1991). In these experiments, the effect of two fragrances, muguet and peppermint, on human vigilance and subjective reports of stress and workload were examined. In the vigilance task, subjects had to watch two parallel lines on a monitor. The distance between the lines increased slightly at random intervals. Subjects were asked to respond to this critical signal by pressing the spacebar on a computer keyboard. Variables recorded were reaction times to the critical stimuli, number of correct responses, number of misses and number of false alarms. Subjective reports of stress and workload were obtained from rating scales. In the course of the vigilance task, odors were delivered to the subjects via oxygen masks for 30 s in every 5 min period. The authors expected that peppermint (traditionally characterized as stimulatory) would have stronger effects on performance measures and that muguet (traditionally characterized as relaxing) would be more effective in reducing subjective ratings of stress and workload, but the results of this study indicated that both substances increased the number of signal detections and thus had positive effects on objective performance but that neither of them influenced subjective reports.

Vigilance is only one of several forms of attention: the term 'vigilance' refers to the sustainment of attention over longer periods of time. Other forms are selective attention or divided attention (Posner and Rafal, 1987). All of these aspects of attention, as well as most other cognitive processing, depend on the most basic component of attention, namely alertness. Alertness in behavioral terms ranges from sleep to wakefulness and may be defined experimentally in terms of speed of information processing. Individual alertness varies with the circadian rhythm and is influenced by many other factors, such as age, general health, degree of stress, anxiety and drugs, and of course depends on the integrity of the nervous system. Aromatherapy in some of its forms aims at improvement of mental performance and efficiency by inhalation of fragrances. This improvement, if it has a physiological basis, should show in an increase in the level of alertness. In the present study, five fragrances were tested for their potentially stimulatory effect.

Materials and methods

Odors and experimental groups

Two pure essential oils (peppermint and ylang-ylang), one absolue ('jasmin absolue ether'; Dragoco charge no. 4900780), and the main components of the essential oils of eucalyptus (1,8-cineole; Aldrich) and peppermint [(1R,2S,5R)-(–)-menthol] were tested for their effects on human alertness.

The investigation consisted of six experiments. In the first two experiments, the essential oil of ylang-ylang (10 µl) and 1,8-cineole (10 µl) were tested. Both the experimental groups and the corresponding control group consisted of 20 healthy human subjects aged between 16 and 67 years. In the third and fourth experiments, the effects of 1,8-cineole (100 µl) and (1R,2S,5R)-(–)-menthol (100 ml of a 50% (w/v) solution in DIGLYME) were investigated. Again, the two experimental groups and the corresponding control group each consisted of 20 healthy human subjects aged between 16 and 67 years. In the fifth and sixth experiments, the effects of the essential oil of peppermint (50 µl, 44% (w/v) menthol) and jasmine absolue ether (100 µl) were determined. In this case, the two experimental groups and the corresponding control group each consisted of 30 healthy subjects aged between 16 and 67 years.

Procedure

An A–B design was used, so that each individual session consisted of two trials. This design was chosen because, with olfactory stimulation, the time course of stimulatory effects is unknown, which might make results obtained from other designs, such as A–B–A, difficult to interpret. In other words, as the time of return to baseline functioning after olfactory stimulation may vary to an unknown degree, the use of an A–B design with experimental and corresponding control groups seemed to us the most promising and economic approach.

At the beginning of each trial, a substance was applied to a surgical mask. In the control groups, this substance was water in both trials, whereas in the experimental groups, this substance was water in the first trial and one of the fragrances in the second trial. Subjects were not informed which substance had been applied, but they were reassured that it was not detrimental to health. Immediately after putting on the mask, subjects were asked to fill in a questionnaire containing visual analogue rating scales of 100 mm length each for four different odor qualities. At the left and right ends of each scale, opposite expressions referring to the highest and lowest rating were placed. Substances were rated subjectively on the dimensions of pleasantness (from 'smells pleasant' to 'smells unpleasant'), intensity (from 'weak' to 'strong'), effect (from 'stimulating' to 'tiring') and degree of relaxation (from 'I feel relaxed' to 'I feel tense'). Subjects then had to perform a simple reaction time task for ~25 min. Subjects sat comfortably in front of a monitor and a small keyboard consisting of two buttons. In each trial, 220 stimuli appeared on the screen. The inter-stimulus interval (ISI) varied between 1000 and 10 000 ms. Each trial started with a black screen. Subjects had to press the 'go' button, which was located next to them on the keyboard, using the index finger of the dominant hand. The stimulus, a red ellipse, appeared at random intervals. Subjects were instructed that, upon appearance of the stimulus, they should release the 'go' button as quickly as possible and press the other button. The time interval from appearance of the stimulus to release of the 'go' button was recorded as reaction time; the time interval from release of the 'go' button to pressing the other button was recorded as motor time. After the stimulus had disappeared, subjects had to return to the 'go' button and a new cycle started.

Data analysis

Differences between the individual mean reaction times, the individual mean motor times and the individual values on the four rating scales in the two trials were calculated for each group. The results of the experimental groups were compared with those of the corresponding control groups by means of Mann–Whitney *U*-test and Kruskal–Wallis one way analysis of variance. Within-group correlations were calculated between subjective odor ratings and differences in reaction and motor time. In addition to statistical analyses, all correlations were inspected visually in order to identify outliers which accounted for statistical significance of the correlation.

Results

The mean motor and reaction times in both trials are depicted in Figures 1 and 2, respectively. Mean differences of the individual reaction times and the individual motor times of all experimental groups and the corresponding control groups are shown in Figure 3. Except for cineole (100 µl), reaction time differences in both the experimental groups and the control groups were negative, i.e. subjects in the second trial showed longer reaction times than those in the first trial. With cineole (100 µl) subjects' reaction times in the second trial were shorter than those in the first trial, resulting in a positive difference. However, none of the reaction time differences in the experimental groups were significantly different from those in the control groups. In contrast, reaction time differences in the cineole groups only marginally failed to reach statistical significance ($U = 131.0$;

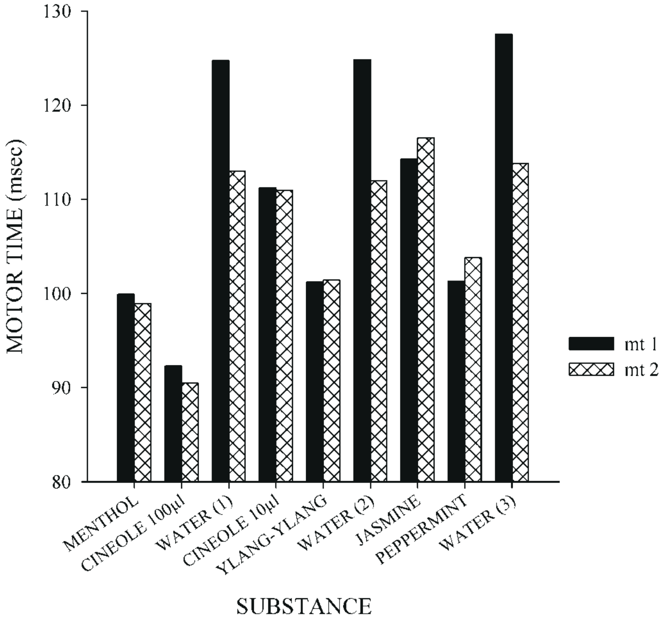

Figure 1 Mean motor times in the first (mt 1) and the second trial (mt 2) for all substances.

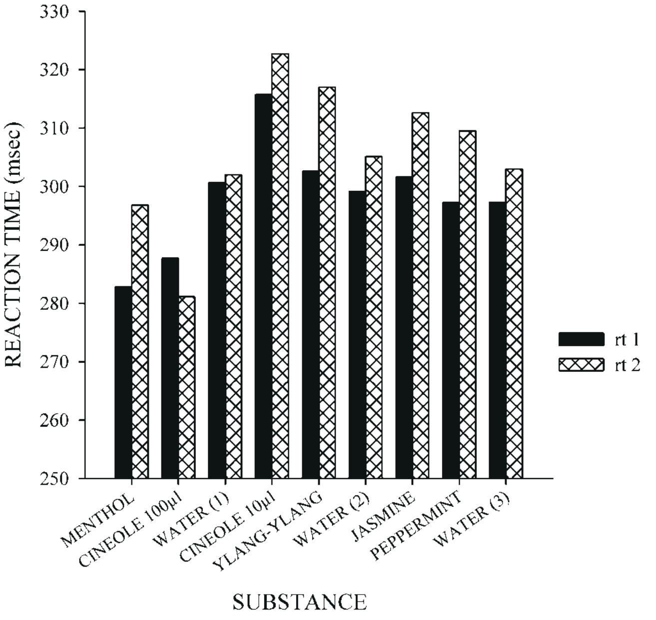

Figure 2 Mean reaction times in the first (rt 1) and second trials (rt 2) for all substances.

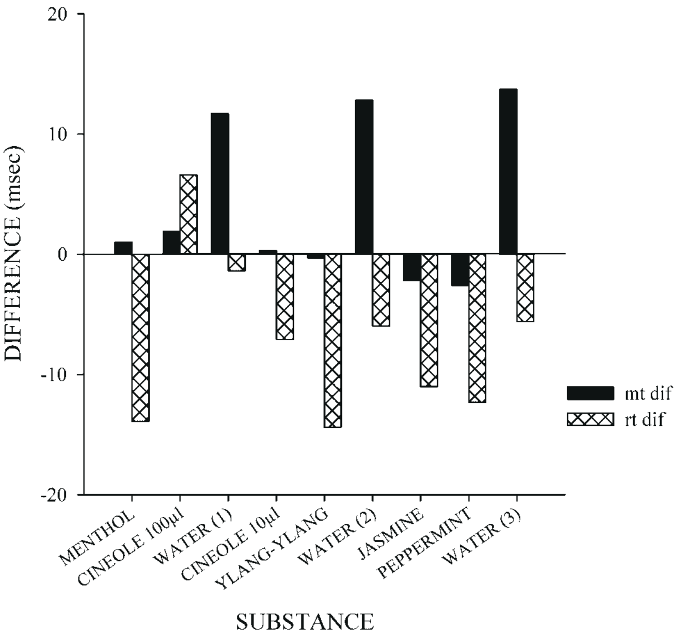

Figure 3 Mean differences in individual reaction times (rt dif) and motor times (mt dif) between the first and second trials for all substances.

P = 0.062). In the second trial, subjects in the cineole (100 µl) group reacted more quickly than those in the cineole (10 µl) group.

For the control groups, positive motor time differences (i.e., acceleration in the second trial compared with the first trial) were found. Menthol and cineole (10 and 100 µl, respectively) yielded rather small positive differences, while for peppermint, jasmine and ylang-ylang even negative differences (i.e., slowing in the second trial compared with the first trial) were found. With cineole (10 µl) (*U* = 292.0; *P* = 0.013), jasmine (*U* = 647.0; *P* = 0.004), peppermint (*U* = 667.5; *P* = 0.001) and ylang-ylang (*U* = 283.0; *P* = 0.025), motor time differences were significantly smaller than in the corresponding control groups. With cineole (100 µl) (*U* = 266.0; *P* = 0.074) and menthol (*U* = 257.0; *P* = 0.060), motor time differences just failed to reach significance.

Mean subjective ratings of the four odor qualities for all substances in both trials are shown in Figure 4. Mean differences in the subjective ratings are shown in Figure 5. Except for ylang-ylang, all substances in the second trial were rated more pleasant than water in the first trial (positive differences). For ylang-ylang a negative difference was found, i.e. the fragrance in the second trial was rated less pleasant than water in the first trial. Only this difference differed significantly from that of the control group (*U* = 302.5; *P* = 0.006). All fragrances in the second trial were rated more intense than water in the first trial, yielding negative differences which were significantly larger than those of water in both trials in the control groups [10 µl cineole, *U* = 351.0, *P* = 0.000; 100 µl cineole, *U* = 389.0, *P* = 0.000; jasmine, *U* = 794.0, *P* = 0.000; menthol, *U* = 357.5, *P* = 0.000; peppermint, U = 800.0, *P* = 0.000; ylang-ylang, *U* = 347.5, *P* = 0.000]. The effect of all substances in the second trial was rated more stimulatory than water in the first trial. The resulting differences in the experimental groups did not differ significantly from those in the control groups. Whereas ylang-ylang and water in the second trial were rated less relaxing than water in the first trial (negative differences), peppermint, menthol, cineole (10 and 100 µl) and jasmine in the second trial made subjects feel more relaxed than water in the first trial (positive differences). However, only for cineole (100 10 µl)l) was the resulting difference significantly larger than that in the corresponding control group (*U* = 109.5; *P* = 0.014).

The results of the correlational analyses are summarized for all groups in Table 1. In the menthol group, a non-linear correlation between individual motor time differences, individual differences of subjectively rated effect of the substances and of degree of relaxation was found (*r* = 0.633, *P* = 0.017), i.e. individual motor times in the second trial increased as the difference between the subjectively experienced effect of menthol (second trial) and that of water (first trial) decreased and as the more subjective relaxation changed between trials. The jasmine group showed a linear correlation between individual motor time differences and subjective evaluation of the effect of the odor in the second trial (*r* = 0.472, *P* = 0.009), i.e. individual motor times in the second trial increased as the rating of the stimulatory properties of the scent of jasmine decreased. Also, a linear correlation between individual motor time differences and individual differences in rated effect of the substances was calculated (*r* = 0.444, *P* = 0.014), i.e. individual motor times in the second trial increased as the rating of the stimulatory ability of the scent of jasmine in the second trial as compared with water in the first trial decreased. For the ylang-ylang group, there was a linear correlation between individual motor time differences and subjectively experienced pleasantness of water in the first trial (*r* = 0.486, *P* = 0.035), i.e. the more pleasant water was judged, the longer motor times were recorded in the second trial. The control group of menthol and cineole (100 µl) [water (1)] showed a non-linear correlation between individual reaction time differences, subjectively rated effect of the substance in the second trial and degree of relaxation in the second trial (*r* = 0.633, *P* = 0.013), i.e. in the second trial subjects in this group reacted more quickly when they felt more relaxed or tense and more slowly when water was rated more tiring or stimulating in this trial.

For the control group given 10 µl cineole and ylang-ylang [water (2)] and for the control group given jasmine and peppermint [water (3)], non-linear correlations between individual motor time differences and individual differences in subjectively experienced effect of the substances [water (2), *r* = 0.605, *P* = 0.005; water (3), *r* = 0.364, *P* = 0.048] as well as between individual reaction time differences and individual differences of subjectively rated effect of the

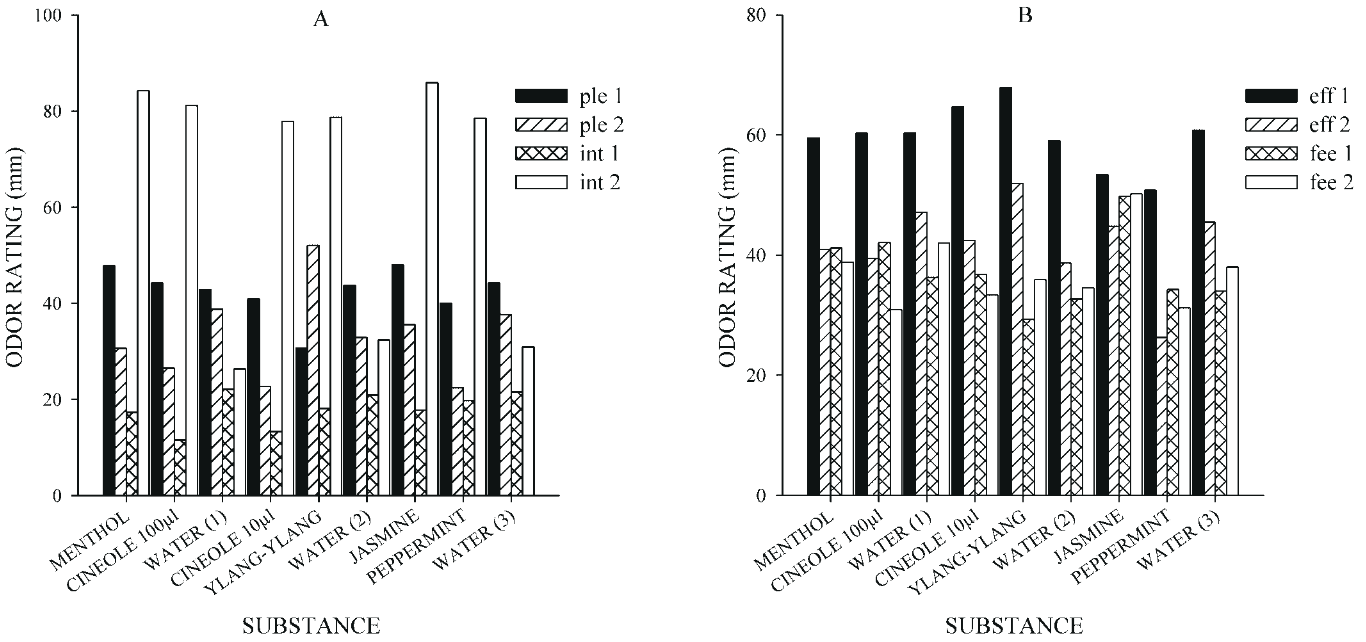

Figure 4 Mean subjective ratings in both trials on odor pleasantness (ple 1, ple 2; **A**), intensity (int 1, int 2; A), effect (eff 1, eff 2; **B**) and degree of relaxation (fee 1, fee 2; B).

substances [water (2), $r = 0.477$, $P = 0.033$; water (3), $r = 0.376$, $P = 0.040$] were found. This means that in both groups, reaction times as well as motor times in the second trial decreased as the difference between the subjectively rated effect of water in the second trial and that in the first trial increased.

Discussion

In our study, the effects of several essential oils on human alertness were measured by single reaction time tasks, in which reaction times were measured separately from motor times. With respect to motor time, all the control groups showed an improvement in motor times from the first to the second trial, indicating motor learning even in this simple motor task (releasing one button and moving to another). None of the experimental groups showed this effect of motor learning; it may be speculated that this is because subjects were distracted by the strong odor stimuli.

Distraction should be even more visible in reaction times and when combined with growing fatigue in the second trial. Indeed, all groups showed negative differences in reaction times from the first to the second trial, and the largest negative differences were in the experimental groups, although the differences between control and experimental groups were not statistically significant.

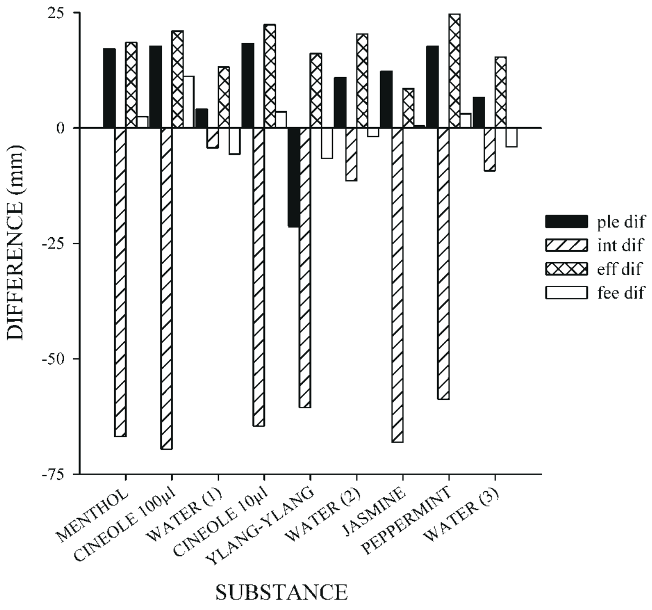

Figure 5 Mean differences in subjective ratings of odor pleasantness (ple dif), intensity (int dif), effect (eff dif) and degree of relaxation (fee dif) between the first and second trials.

There was one exception with respect to reaction time differences, and that was the cineole (100 µl) group, in which there was a positive reaction time difference. Comparison of this difference with the negative difference in reaction time of the cineole (10 µl) group revealed a trend towards significance; as intensity ratings did not differ between these two experimental groups, the effect may have been a non-psychological one, indicating that rather high dosage of agents is necessary to influence biochemical and physiological levels of activation in a purely pharmacological way if these agents are applied by means of inhalation. Comparison of two other experimental groups, i.e. the menthol and the peppermint group, supports this hypothesis. The

Table 1 Correlations between individual reaction times, individual motor times and subjective odor ratings for all substances

Substance	Difference[a] in	Pleasantness (trial 1)	Effect (trial 2)	Difference[a] in effect	Degree of relaxation (trial 2)	Difference[a] in degree of relaxation
Menthol	motor time			∪		∩
Jasmine	motor time		\	/		
Ylang-ylang	motor time	/				
Water (1)	reaction time		∩		∪	
Water (2)	motor time			∪		
	reaction time			∪		
Water (3)	motor time			∪		
	reaction time			∪		

/, Positive linear relation; \, negative linear relation; ∪, non-linear correlation, U-shaped; ∩, non-linear correlation, inverse U-shaped.

[a] Difference between trials 1 and 2.

amount of menthol applied to the mask was 0.05 g in the menthol group and 0.022 g in the peppermint group. No significant effects were found when reaction time differences were compared between these two groups, indicating that, in contrast to 1,8-cineole, the increase in dosage of menthol was not sufficient to overcome distraction. However, we did not control breathing behavior and so we cannot determine the actual amount of substances inhaled by the subjects in our experiments.

With regard to subjective ratings, the estimations of change in intensity in all the experimental groups differed significantly from those in the control groups, i.e., subjects clearly perceived the presented odors. As for the other ratings, only ylang-ylang was perceived as differing significantly in pleasantness, while cineole (100 μl) led to an increased feeling of relaxation when compared with the first trial. There were no correlations of those difference measures with the behavioral data, indicating that the amount of subjectively estimated changes is not an important factor for changes in alertness in these cases. However, there was a significant correlation between subjective estimations of pleasantness of the substance in the first trial (i.e., water) and motor time differences in the ylang-ylang group. The more pleasant that subjects rated water as, the more negative the motor time differences were: it may be speculated that if water in the first trial was experienced as pleasant, and if this was followed by ylang-ylang, which was generally experienced as unpleasant, subjects could have been distracted by the presence of this unpleasant odor, resulting in longer reaction times in the second trial. As there were neither correlations between motor time difference and subjective estimations of pleasantness of the ylang-ylang oil nor between motor time differences and difference scores of pleasantness, the effect must depend on perceived qualities of the first substance. Another example shows the influence of jasmine on motor time differences: the less stimulatory this substance was experienced as, the more negative motor time differences were. This is very straightforward evidence for the impact of subjective feelings about a substance on overt behavior. From these examples it follows that the fact that inter-group differences in behavioral data are mainly non-significant should not lead to the conclusion that they are not influenced by the substances tested. This influence, however, is based on the perceived qualities of the substances and revealed only in intra-group analysis. The mainly psychological nature of the observed effects is most convincingly demonstrated by the significant correlations between the differences in effectivity ratings and motor and reaction time differences in the control groups, when the substance applied twice was water. In this case correlations indicate that the more stimulatory water was judged to be in the second trial when compared with the first trial, the more positive reaction time as well as motor time differences were, which clearly is a placebo effect.

Essential oils, and even water, are thus perceived differently by different subjects, leading to differential effects on behavioral measures like motor times. In addition, subject groups can be heterogeneous in other ways, such as motivation and initial level of alertness, generating additional variance in experimental variables. A subject who feels inattentive is more likely to benefit from the administration of an activating fragrance than a subject who reports that they are alert (Nelson *et al.*, 1995). Also, subjects' expectations of a substance's effect may affect motivation and, therefore, behavior (Baron, 1990), even if the presence of that substance is suggested (Knasko *et al.*, 1990). Gender (Baron, 1990; Gilbert *et al.*, 1997) and personality traits (Ludvigson and Rottman, 1989; Knasko, 1992; Kerl, 1997) also seem to be involved in the effects of fragrances on humans.

In a critical but very constructive survey, Jellinek (Jellinek, 1997), distinguishes four mechanisms on which psychodynamic odor effects may be based: (i) a quasi-pharmacological mechanism influencing the central nervous or hormonal systems; (ii) a semantic mechanism accounting for the influence of personal experiences with certain odors;

(iii) a hedonic valence mechanism providing the dimension of pleasantness for emotional states; and (iv) a placebo mechanism which is based on subjective expectation. All of those mechanisms may be active in subjects who take part in experiments on olfaction, and it may be very difficult, if not impossible, to disentangle their differential influences on the experimental results. Different designs or use of odor–odor control groups may be useful in future research, as only additional and carefully designed studies will bring us further understanding of the complex interactions of odor exposure with personal, subjective factors.

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