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The Impact of Natural Odors on Affective States in Humans

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Abstract

Laboratory studies have shown a significant influence of certain fragrances on affective as well as cognitive states in humans. The aim of the current study was to measure the relationship between complex, natural odors and affective states, that is, calmness, alertness, and mood, in the field. In 4 experiments, the emotional impact, intensity, and hedonics of complex, natural plant odors were assessed in 32 healthy human subjects and compared with control conditions involving a similar outdoor environment without the tested fragrant plants. In all experiments, the selected fragrances were evaluated as more intense than the odors in the control conditions but pleasantness ratings differed only in 2 of the 4 experiments. The fragrances improved subjective ratings of calmness, alertness, and mood depending on the sequence of the conditions but independent of visual features of the environment. In contrast, a fifth experiment which tested the influence of natural and artificial pleasant odors and an artificial unpleasant odor on calmness, alertness, and mood in 22 subjects showed that the unpleasant odor impaired these affective states in humans independent of the order of presentation. On the other hand, no effects of the pleasant odors on mood and calmness were observed in this experiment.

Key words: affect, intensity, olfaction, valence, well-being

Introduction

A number of laboratory studies suggest a close relationship between olfactory and affective information processing (Zald and Pardo 1997; Rouby et al. 2005). Early studies have already demonstrated that olfactory stimuli can trigger both positive and negative affect in humans (Ehrlichman and Halpern 1988). Recent investigations suggest that odors can modulate mood (Goel and Grasso 2004), cognition (Hermans et al. 1998; Heuberger et al. 2001; Millot et al. 2002; Herz 2004; Lehrner et al. 2005), and behavior (Millot and Brand 2001). Autonomic parameters which are considered objective indicators of different affective states (Ekman et al. 1983; Collet et al. 1997; Christie and Friedman 2004) are influenced by certain olfactory cues (Alaoui-Ismaili et al. 1997; Moller and Dijksterhuis 2003). Moreover, effects of odor stimuli on cerebral activity were revealed by electrophysiological recordings (Sobel et al. 1999; Kline et al. 2000) and neuroimaging methods (Sobel et al. 1999; Royet and Plailly 2004). It has been demonstrated that pleasant odors positively affect mood and decrease arousal, whereas unpleasant odors have opposite effects (Knasko 1992; Alaoui-Ismaili et al. 1997; Inoue et al. 2003). On the other hand, strong odors induce higher arousal than weak odors (Bensafi et al. 2002; Royet et al. 2003; Heuberger et al. 2006) while the relationship between odor intensity and mood is less clear.

Although in many laboratory studies a strong link between olfactory stimuli and affective states has been demonstrated in humans, at present there are no attempts to investigate this relationship in the field. Thus, our study aimed to determine the influence of natural fragrances, that is, the smell of certain fragrant plants, on affective states, that is, mood, alertness, and calmness, in humans in a natural, outdoor setting. To record the valence and intensity of the tested fragrances, participants gave ratings of their olfactory perceptions. As experimental location we chose the so-called "Duftgarten" (Fragrant Garden) at the University of Natural Resources and Applied Life Sciences in Vienna. The Fragrant Garden is an experimental garden which, in contrast to traditional gardens, primarily addresses the olfactory sense of the visitors and is designed to combine a variety of fragrant plants into a harmonious blend of odors throughout the growth period.

Materials and methods

Experimental design and procedures

Five experiments were conducted at 2 locations (Table 1). Experiments 1–4 were carried out within the surroundings of a garden of the University of Natural Resources and

Table 1 Overview of the experiments conducted at the Fragrant Garden and the Garden at the Department of Clinical Pharmacy and Diagnostics

Experiment number	Location	Month and time of day	Order of conditions
1	FG	May, daytime	C, E
2	FG	June, daytime	E, C
3	FG	July, daytime	E, C
4	FG	July, nighttime	C, E
5	DCPD	July, daytime	Counterbalanced V, F, H, W

Fragrant Garden (FG)—C: control condition, evaluation of affective state, odor pleasantness, and intensity, and E: experimental condition, sniffing/smelling at selected fragrant, blooming plants, evaluation of affective state, odor pleasantness, and intensity; Department of Clinical Pharmacy and Diagnostics (DCPD)—sniffing/smelling vanillin (V), floral (F, jasmine or rose), H_2S (H), or odorless water (W) from plastic squeeze bottles, evaluation of affective state, odor pleasantness, and intensity.

Applied Life Sciences at several time points between May and July 2007. In each of these experiments, 2 outdoor conditions were defined: an experimental condition (E) which took place at the Fragrant Garden in which subjects perceived complex natural odors, that is, the smell of selected fragrant, blooming plants, and a control condition (C) which was located in a different part of the garden without any olfactory design about 100 m away from the experimental setting and which differed from the experimental condition in terms of the olfactory stimuli, that is, subjects were not exposed to the smell of any fragrant, blooming plants. Auditory and visual stimuli were held constant between the conditions. Affective reactions to the odor stimuli were measured with the "Mehrdimensionale Befindlichkeitsfragebogen" (MDBF questionnaire, Steyer et al. 1997). The dependent variables were mood, alertness, and calmness. In addition, subjective ratings of odor pleasantness and intensity were assessed on 100-mm visual analog scales.

The first experiment at the Fragrant Garden was conducted in May and consisted of the above-described conditions (E and C). The experiment started with the acquisition of relevant personal data, such as name, age, and sex of the subjects (about 5 min), followed by the control condition which lasted for approximately 15 min. Subjects were sitting on benches, were not allowed to talk to each other, and were instructed to evaluate the atmosphere in the control environment. Then, subjects filled out the MDBF questionnaire and gave ratings of odor pleasantness and intensity of the surrounding environment. In this condition, subjects were not instructed to sniff or smell at any specific plants because we were interested in the influence of the odors of the chosen fragrant plants compared with a garden without any olfactory design rather than the difference between high-odor and low-odor plants. After completing the forms, subjects were guided to the experimental location and the experimental condition started. This condition lasted for approximately 15 min and consisted of smelling and/or sniffing at the selected fragrant plants 3 times each. Then subjects again filled out the MDBF questionnaire and rating scales.

To check for order effects, 2 additional experiments (2 and 3) were performed at the Fragrant Garden in June and July in which the order of the experiment was reversed, that is, a E–C design was used instead of the C–E design described above.

To control for specific influences of visual input from the environment at the Fragrant Garden, such as the color and shape of the flowering plants (Schifferstein and Tanudjaja 2004) producing the odor stimuli, another experiment at the Fragrant Garden in July was carried out at night (experiment 4), when certain fragrant plants, known to release their characteristic scent after dusk, were in their bloom. In this experiment, the same design was used as in the first experiment.

Experiment 5 was conducted in July at a garden at the Department of Clinical Pharmacy and Diagnostics. This experiment was designed to assess the influence of odor valence on affective states. A counterbalanced design with 3 experimental conditions and a control condition was employed which carefully controlled for habituation and order effects (Baumgartner et al. 2006). In 2 of the 3 experimental conditions, several pleasant odors (see Stimuli) were presented with plastic squeeze bottles that were held approximately 5 cm underneath the subject's nose. In the third experimental condition, an unpleasant odor was presented, whereas in the control condition a neutral stimulus, that is, odorless water, was presented instead of a fragrance by the same procedure. Each condition lasted for approximately 15 min. First, one of the squeeze bottles was presented and subjects were instructed to take 3 sniffs and to fill out the MDBF questionnaire and rating scales. Then, subjects were allowed to rest while sitting quietly in order to minimize carryover effects.

Subjects

In total, 32 healthy and neurologically inconspicuous individuals (74.3% females) with a mean age of 24.3 years (range 17–36) participated in this study. Thirty-two subjects took part in the first experiment at the Fragrant Garden in May. Twenty-nine subjects took part in experiment 2, 25 in experiment 3, and 30 in experiment 4. Experiment 5 at the Department of Clinical Pharmacy and Diagnostics in July was conducted with 22 individuals. All participants were recruited by advertisement at the University of Vienna. They were free to withdraw at any time and were compensated for their time commitment.

Stimuli

The stimulus material used in the experiments (1–4) at the Fragrant Garden consisted of the fragrances of selected, blooming plants. In experiment 1 in May, subjects were presented with the odors of *Convallaria majalis* L. (Liliaceae), *Jasminum sambac* L. (Oleaceae), *Dictamnus albus* L. (Rutaceae), *Rosa x alba* L. (Rosaceae), *Iris graminea* L. (Iridaceae), *Phlox divaricata* L. (Polemoniaceae), *Rosa x damascena* L. (Rosaceae), and *Paeonia officinalis* L. (Paeoniaceae). In experiment 2 in June, subjects smelled the odors of *Lilium regale* Wils. (Liliaceae), *Hemerocallis lilioasphodelus* L. (Liliaceae), *Matthiola bicornis* (*Sm.*) *DC.* (Brassicaceae), and *Reseda odorata* L. (Resedaceae). In experiment 3 in July, *Hosta* sp. (Hostaceae), *Lathyrus odoratus* L. (Fabaceae), *Matthiola incana R.Br.* (Brassicaceae), and *Saponaria officinalis* L. (Caryophyllaceae) were in bloom. During experiment 5 in July, subjects were presented with the fragrances of *Lonicera japonica* L. and *Lonicera periclymenum* L. (Caprifoliaceae), and of *Hemerocallis citrina L.* (Liliaceae).

In experiment 5 at the garden of the Department of Clinical Pharmacy and Diagnostics, the pleasant odor stimuli were the vapors of dilutions of vanillin (1 mg/ml propylene glycol) and jasmine absolute or rose oil (2 µl/ml propylene glycol and diethyl phthalate, respectively). One half of the subjects received jasmine, the other half received rose odor in this condition. In the unpleasant condition, a solution of sodium sulfide (2.5 mg/ml water) was used. The neutral stimulus was odorless water. The stimuli were presented with 250-ml opaque high-density polyethylene squeeze bottles containing 50 ml of solution.

Statistical analysis

To evaluate the emotional impact of the stimuli in the experiments conducted at the Fragrant Garden (1–4), the scores in each category of the MDBF questionnaire, that is, mood, alertness, and calmness, in the experimental conditions were compared with the data collected in the corresponding control conditions by means of paired samples *t*-tests. In addition, pleasantness and intensity ratings obtained in the experimental conditions were compared with those given in the control conditions to ensure that the fragrances perceived in the experimental conditions were actually rated differently in relation to any ambient odors perceived in the corresponding control conditions.

In experiment 5 performed at the Department of Clinical Pharmacy and Diagnostics, the influence of pleasant and unpleasant olfactory stimuli on the dependent variables and potential order effects were analyzed with repeated-measures 2-way multivariate analyses of variance (MANOVAs) using Greenhouse-Geisser–adjusted degrees of freedom followed by post hoc paired samples *t*-tests. Post hoc comparisons were calculated using Bonferroni corrected *P* values to control for α inflation. We decided to test 2 different pleasant odors in experiment 5 but not to distinguish between them in the statistical analysis because in the outdoor setting in experiments 1–4 participants were exposed to several pleasant odors at the same time.

Results

In experiment 1 at the Fragrant Garden, paired samples *t*-tests revealed significant differences between the experimental and control condition indicating an increase in mood ($P = 0.001$), alertness ($P = 0.000$), and calmness ($P = 0.000$) in the experimental condition. Furthermore, the odorous atmosphere at the Fragrant Garden was rated as more pleasant ($P = 0.000$) and more intense ($P = 0.000$) than the corresponding control condition (Figure 1).

Experiments 2 and 3—reversed experimental setup at the Fragrant Garden

Paired samples *t*-tests revealed no significant differences between the experimental condition and the control condition

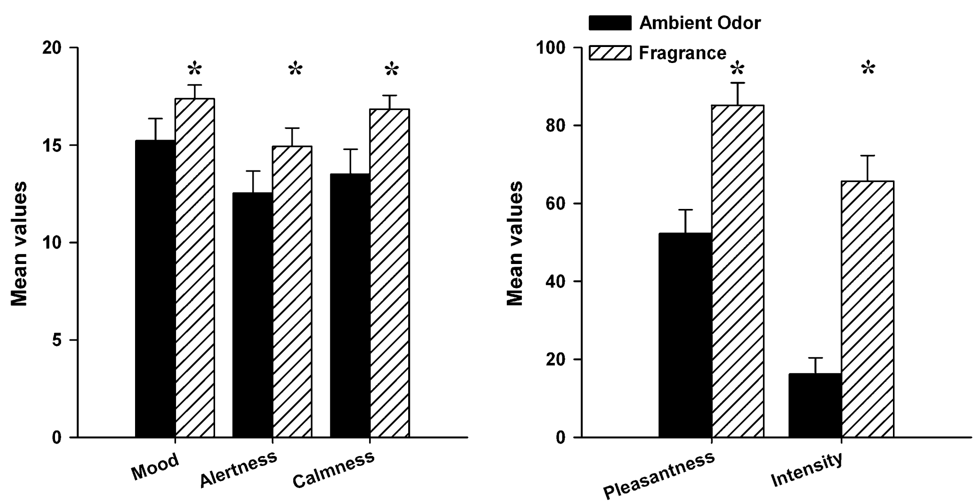

Figure 1 Mean values (±95% confidence interval) of alertness, calmness, mood (left), pleasantness, and intensity (right) in the control and experimental conditions in the experiment 1 at the Fragrant Garden in May 2007. *Differs significantly ($P < 0.001$) from control condition.

in experiment 2. Nevertheless, contrasting the mean values of the pleasantness and intensity ratings showed that the odorous atmosphere in the experimental condition was rated as more intense (P = 0.007) but not more pleasant than the atmosphere in the control condition. Similarly, no significant differences were found between the experimental condition and the control condition in experiment 3. However, in the latter experiment, the odorous atmosphere in the experimental condition was rated as more pleasant (P = 0.001) and more intense (P = 0.000) than the atmosphere in the control condition (Figure 2).

Experiment 4—control of visual input

Paired samples t-tests revealed significant differences between the experimental condition and the control condition, indicating an increase in mood (P = 0.001), alertness (P = 0.000), and calmness (P = 0.000) in the experimental condition at the Fragrant Garden at night. Moreover, the pleasantness and intensity ratings showed that the smell of the fragrant plants was judged to be more intense (P = 0.000) but not more pleasant than the atmosphere in the corresponding control condition (Figure 3).

Experiment 5—order effects and influence of valence

The influence of pleasant and unpleasant olfactory stimuli on mood, alertness, and calmness, and potential order effects were analyzed by a repeated-measures 2-way MANOVA with the within-subjects factors "valence" (vanillin, jasmine absolute or rose oil, hydrogen sulfide, and odorless water) and "affect" (alertness, calmness, and mood). Significant main effects for valence ($F_{3,63}$ = 3.778; P = 0.027) and affect ($F_{2,42}$ = 6.651; P = 0.004) as well as a significant interaction between the 2 factors ($F_{6,126}$ = 4.761; P = 0.001) were found. The influence of pleasant and unpleasant olfactory stimulation on pleasantness and intensity ratings as well as potential order effects were tested by a separate repeated-measures 2-way MANOVA with the within-subjects factors "valence" (vanillin, jasmine or rose oil, hydrogen sulfide, and odorless

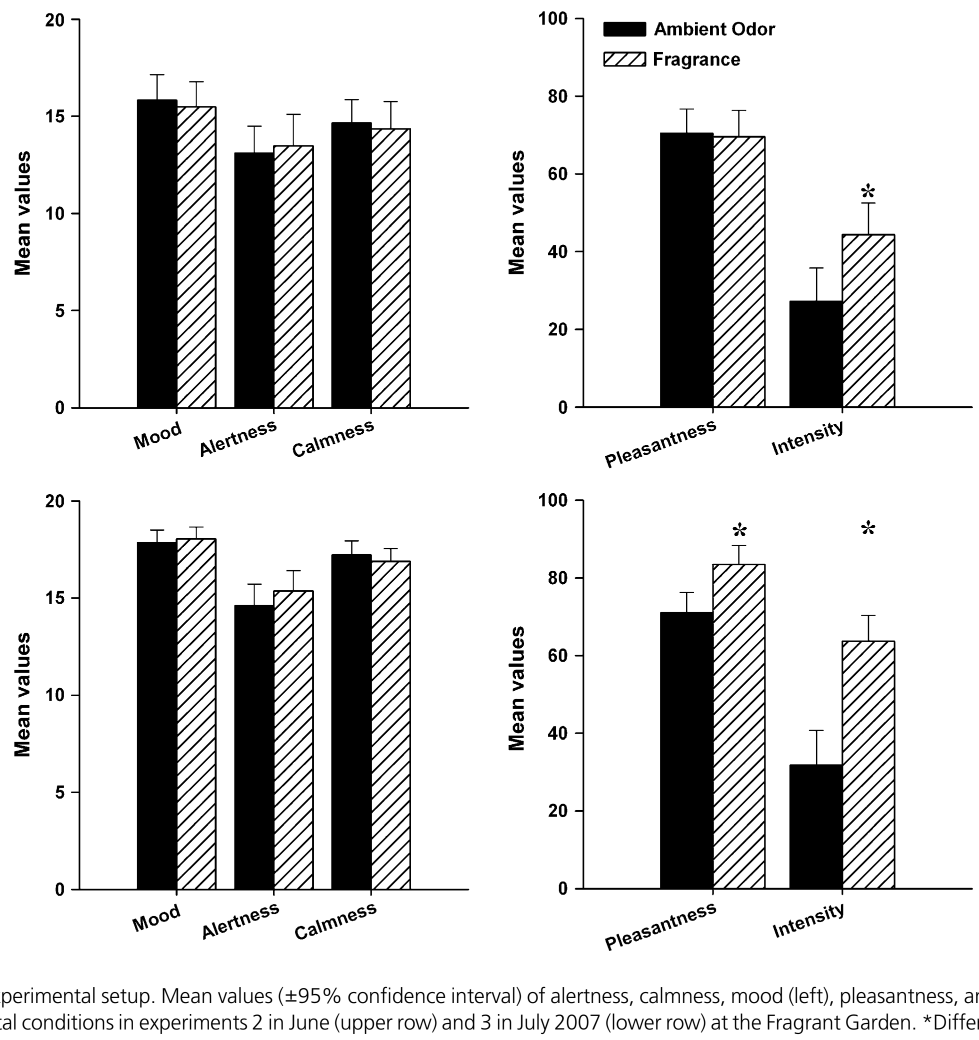

Figure 2 Reversed experimental setup. Mean values (±95% confidence interval) of alertness, calmness, mood (left), pleasantness, and intensity (right) in the control and experimental conditions in experiments 2 in June (upper row) and 3 in July 2007 (lower row) at the Fragrant Garden. *Differs significantly (P < 0.01) from control condition.

water) and "rating" (pleasantness and intensity). The analysis revealed a significant main effect for valence ($F_{3,63}$ = 25.693; P = 0.000) and a significant interaction between valence and rating ($F_{3,63}$ = 12.974; P = 0.000). To account for the significant main effects and interactions, post hoc paired samples *t*-tests were calculated. Bonferroni corrected *P* values are reported.

For the affective measures, the Paired Samples *t*-tests showed significant differences between the hydrogen sulfide and neutral conditions, indicating a decrease in mood (P = 0.002) and calmness (P = 0.030) but not in alertness in the hydrogen sulfide condition. The tests for the pleasantness and intensity ratings showed that the smell of hydrogen sulfide was judged to be more unpleasant (P = 0.000) and more intense (P = 0.010) than odorless water (Figure 4).

The paired samples *t*-tests revealed no significant differences of the affective measures between the vanillin and neutral conditions. However, vanillin was rated as more pleasant (P = 0.000) and more intense (P = 0.013) than odorless water. Similarly, no significant differences were found between the floral and neutral conditions concerning mood and calmness. Interestingly, alertness was significantly higher (P = 0.040) in the floral than in the neutral condition. Furthermore, the odors of rose oil and jasmine absolute were judged more pleasant (P = 0.001) and more intense (P = 0.001) compared with odorless water (Figure 4).

The paired samples *t*-tests revealed significant differences between the vanillin and hydrogen sulfide conditions, indicating an increase in mood (P = 0.021) and calmness (P = 0.011) but not in alertness in the vanillin condition. Contrasting the mean ratings of pleasantness and intensity showed that the smell of vanillin was rated as more pleasant (P = 0.000) but not more intense than the smell of hydrogen sulfide. Furthermore, significant differences were found

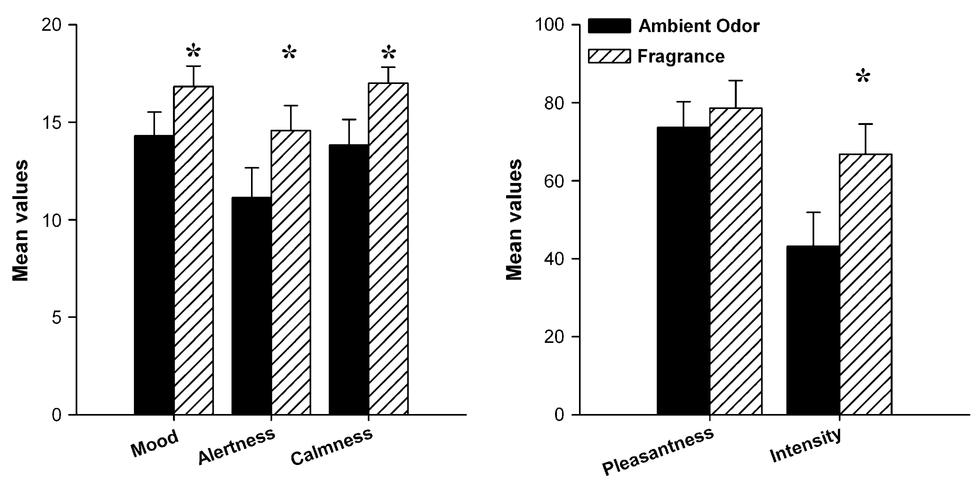

Figure 3 Control of visual input. Mean values (±95% confidence interval) of alertness, calmness, mood (left), pleasantness, and intensity (right) in the control and experimental conditions in experiment 4 at the Fragrant Garden at night in July 2007. *Differs significantly (P < 0.001) from control condition.

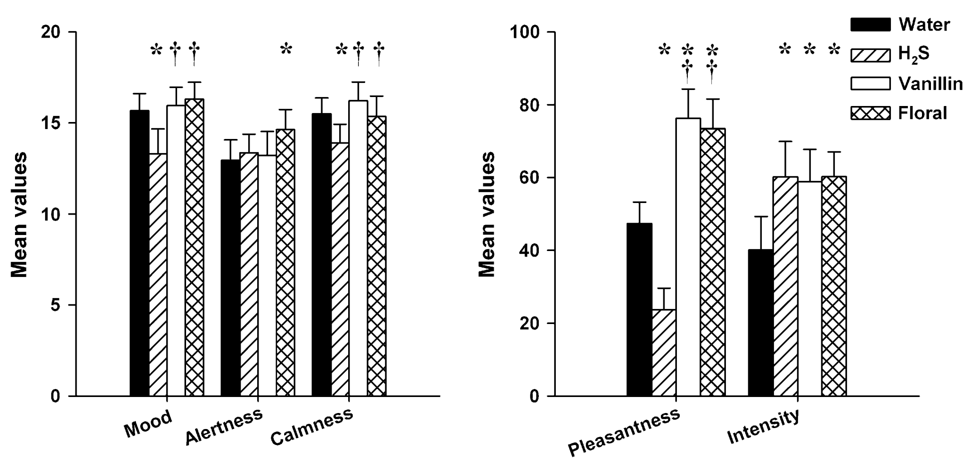

Figure 4 Mean values (±95% confidence interval) of alertness, calmness, mood (left), pleasantness, and intensity (right) in all conditions in the control experiment at the Department of Clinical Pharmacy and Diagnostics in July 2007. Floral: jasmine or rose odor. *Differs significantly (P < 0.05) from odorless water. †Differs significantly (P < 0.05) from H_2S (unpleasant).

between the floral and hydrogen sulfide conditions, indicating an increase in mood ($P = 0.005$) and calmness ($P = 0.029$) but not in alertness in the floral condition. Also, comparing the mean values of odor pleasantness and intensity showed that the smells of jasmine absolute and rose oil were judged to be more pleasant ($P = 0.000$) but not more intense than the smell of hydrogen sulfide (Figure 4).

Discussion

The results of the first experiment at the Fragrant Garden showed that complex, natural odors derived from blooming plants increase calmness, alertness, and mood, in humans in a natural, outdoor setting. Furthermore, the selected locations within the Fragrant Garden were evaluated as more pleasant and more intense than the corresponding control locations. These results confirm the findings of previous research conducted in indoor environments and in the laboratory (Lehrner et al. 2000, 2005; Tildesley et al. 2005; Warrenburg 2005). Our findings indicate that the beneficial effects of pleasant odors are also present in a natural environment and can be induced by complex odors, such as scents of flowering plants.

These results were questionable in terms of possible influences of certain color and shape settings as well as of order effects, and in experiment 1 at the Fragrant Garden, we did not test the influence of unpleasant olfactory stimuli on mood, alertness, and calmness. To evaluate the impact of these potentially confounding variables, we designed additional experiments. In regard to order effects, we hypothesized that the beneficial effects of pleasant odors on the affective state would be compensated by a consecutive neutral or at least less pleasant odor. However, this was not the case in either of these experiments. First, there was no difference between the hedonic evaluations in the experimental and control conditions in experiment 2. This may be due to the bad weather conditions, that is, hail and a dramatic drop in temperature just prior to the time of testing, which might have reduced the volatility of the fragrances. The intensity ratings also seemed to be affected by these circumstances, although not as much as the hedonic evaluations. Second, even though in the measurement in July (experiment 3) ratings of odor pleasantness and intensity differed as we predicted, no significant differences between the control condition and the experimental condition were found for mood, alertness, and calmness. Our interpretation of these results is that the beneficial effect on affective states of natural, complex fragrances is a relatively long-lasting phenomenon that is persistent in a subsequent control condition.

From experiment 5 at the Department of Clinical Pharmacy and Diagnostics, we conclude that unpleasant odors impair the affective state of healthy subjects and reverse the enhancing effect of pleasant fragrances on mood, alertness, and calmness independent of the sequence of presentation. In this experiment, we found no significant overall difference between pleasant and neutral conditions. Visual inspection of the data showed that the affective ratings in the neutral odor condition were higher when a pleasant odor preceded the neutral odor than when the presentation of a pleasant odor was followed by that of the neutral odor. In contrast, the affective ratings in the pleasant odor conditions remained relatively stable irrespective of the sequence of conditions. These results support our hypothesis that the effects of pleasant odors are longer lasting and thus still present in consecutive control trials. In contrast, the effect of unpleasant olfactory stimulation seemed to be relatively transient as indicated by the significant overall differences between unpleasant and neutral trials and between unpleasant and pleasant conditions, respectively. Hence, unpleasant odors did not diminish the affective state in successive neutral control trials as a result of carryover processes. Nevertheless, we cannot fully rule out the possibility that the observed order effects are confounded with differences between natural and artificial odors. In addition, in this experiment, subjects were instructed to actively sample the neutral odor but they were not told to sniff in any (neutral) control condition in the experiments at the Fragrant Garden. This difference in experimental design may also have contributed to the different results in the 2 types of experiments.

As we intended, the intensity ratings were equal between pleasant and unpleasant olfactory stimuli. This finding may explain why alertness scores of our subjects did not differ between the experimental conditions A, B, and C. Similar observations have been reported for visual emotion inducing material (Pollatos et al. 2007). Our results are also in line with recent findings, which indicate that stimulating odors are able to increase alertness while subjects are awake (Goel and Lao 2006).

Regarding the influences of visual input (Schifferstein and Tanudjaja 2004) on affective states, we found similar effects when comparing the data obtained at the Fragrant Garden at night with those in broad daylight. Hence, it seems that visual features of the environment did not account for the improving influence of natural odors on the affective state of humans. It is important to note, however, that the control condition in the experiment at night was different from that during daytime because linden trees present in the original control environment were in full bloom at the time of the experiment during nighttime. Nevertheless, some participants reported to have perceived a pleasant but unidentifiable smell in the control condition at night. This may account for the nonsignificant difference of the pleasantness ratings between the experimental condition and the control condition at night.

The overall results show that natural odors improve affective states in humans in a natural, outdoor setting independent of visual input. These findings may be interesting for landscape architects, for example, for the improvement of urban environments as well as for psychotherapists working with outdoor settings, such as garden therapists.

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