Aroma-Chology: A Status Review

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1. Definition

The term *Aroma-Chology* (a Service Mark of the Olfactory Research Fund) was coined in 1982 to denote the science that is "dedicated to the study of the interrelationship between psychology and ... fragrance technology to elicit a variety of specific feelings and emotions—relaxation, exhilaration, sensuality, happiness and wellbeing—through odors via stimulation of olfactory pathways in the brain, especially the limbic system."[1]

Prior to the introduction of the term *Aroma-Chology*, the effects of fragrances on feelings and emotions were usually subsumed under the heading *Aroma Therapy*, a practice which gave rise to considerable confusion since the focus and the approach of the new science of Aroma-Chology differ in several crucial respects from those of the traditional art of aroma therapy. Because the confusion persists even today, a detailed look at the implications of the above definition of Aroma-Chology is in order.

1. Aroma-Chology is a science in the rigorous sense. It seeks to establish relationships that are verifiable through reproducible experiments that can be expressed in quantitative terms and whose statistical significance can be determined. It is not content with individual case histories.
2. Aroma-Chology is concerned only with the temporary effects of fragrance on feelings and emotions. It does not deal with therapeutic effects on conditions such as chronic depression, sleeping disorders or somatic dysfunctions.
3. Aroma-Chology deals only with effects achieved through stimulation of olfactory pathways in the brain. It does not deal with effects attained through the introduction of active agents into the bloodstream by means of ingestion or of transdermal absorption resulting from application by massage.
4. Aroma-Chology measures effects of blends of odorants (perfume compounds) as well as those of single odors materials, both natural and synthetic. It neither confines itself nor ascribes any particular virtue to purely natural odor materials.
5. The aroma therapy literature is marked by a tendency implicitly to ascribe whatever effects are observed to a direct action of odorant molecules upon the central nervous system, bypassing the cognitive centers of the brain. Sedative or stimulant, anxiety-relieving or anti-depression effects are ascribed to specific essential oils without reference to any cognitive mechanism (such as recognition or associations) that may mediate such effects.[2] Aroma-Chology literature, on the other hand, explicitly acknowledges the possibility of cognitive mediation of effects and includes fragrance applications in which such mediation is almost certain to occur.

The term *Aroma Science* has been used by some recent authors in the same sense in which *Aroma-Chology* is used here. We prefer *Aroma-Chology* for two reasons:

- The term *Aroma Science*, being rather general, may lead to misunderstandings. It may, for example, be believed to refer to chemical aspects of aroma.
- Important recent work in the area has been conducted under the aegis of the Fragrance Research Fund which in 1993 changed its name to Olfactory Research Fund. In the reports on this work, the term *Aroma-Chology* has consistently been used.

2. Scope and Structure of this Review

During the past ten years, a considerable amount of research has been conducted in the United States, in Europe and in Japan to measure not only the effects of fragrances upon feelings, moods and emotions, but also upon several related areas of response: electrical activity in the brain, physiological parameters such as heart rate and skin conductance, cognitive functions such as memory, and voluntary and involuntary behavior.

In the present paper, findings in all of these areas will be reviewed, but only studies on human subjects will be considered. Not included in this review is the extensive body of work related specifically to responses to human body odor and its components. Reference will be made not only to reports published in books and professional journals, but also to abstracts of papers presented at meetings of the Association for Chemo-Reception Sciences (AChemS), the European Chemo Research Organisation (ECRO), the Japanese Association for Smell and Taste Sciences, as well as reports to the Fragrance Research Fund/Olfactory Research Fund. The paper represents an updating and extension of earlier reviews by Carsh,[3] Indo[4] and Lawless.[5]

3. Review of Findings

3.1—Odors and Electrical Brain Activity

Major investigations in this area have been conducted in the U.S.A. by Lorig and his co-workers[6,7] at Washington and Lee University, in the U.K. by the Warwick Human Chemo-Reception Research Group led by van Toller,[8,9] in Germany at the University of Erlangen by a group led by Kobal[10,11] and by several research groups in Japan. Such measurements are relevant to Aroma-Chology to the extent that consistent relationships can be found between specific features of the recordings of electrical activity and measurable effects of the odorous stimuli upon mood or feelings.

3.1.1—*Evoked potentials:* Kobal et al[10,11] found differences between the evoked potentials in relation to the nostril to which the stimulus was offered, along with evidence that the differences were related to the pleasantness of the stimuli. With vanillin, phenylethyl alcohol and with acetaldehyde in low concentrations (these are stimuli that were rated pleasant by test persons), response latencies (time lapsed between presentation of the stimulus and the onset of response) and the magnitude of the response peak were greater when the odor was presented to the left nostril only. With hydrogen sulphide, carbon dioxide, acetaldehyde at high concentrations and menthol (the first three of these were universally rated unpleasant, menthol received mixed ratings) this pattern was reversed. The tests were conducted with right-handed naive subjects only. The authors believe that the "topographical differences of the potentials, caused by stimulation of the different sides, were related to the manner in which the two hemispheres process emotional information of different qualities." They point to previous publications in which it has been reported that pleasant emotions are predominantly processed by the left hemisphere and unpleasant emotions more often by the right one. They found, moreover, that the side/hedonic interaction occurred in the very early phases of the olfactory-evoked response, where cognitive processing has not yet taken place.[11a] They conclude that the difference in hedonic quality (pleasantness) between hydrogen sulfide and vanillin is "generated subcortically," which implies that this difference is not learned or conditioned but innate and "hard-wired."

Confirmation of the thesis of side/hedonic interaction comes from earlier work of Ehrlichman[12] who reported that unpleasant odors were rated as more unpleasant when presented to the right nostril (which projects to the right hemisphere) than when presented to the left. Similarly, Saito et al,[13] exploring brain responses to lemon oil and to isovaleric acid, found that the left hemisphere responded more strongly to lemon oil while the right hemisphere was more responsive to isovaleric acid.

3.1.2—*Contingent negative variation:* The "contingent negative variation" (CNV) is a slow negative brain potential occurring between the presentation of a warning stimulus (S1) and an imperative stimulus (S2) which calls for immediate action on the part of the test subject. Torii et al[14,32] studied the effect of odor stimuli on the early portion of the CNV and found that the presentation of jasmin odor causes a significant increase in the CNV measured at frontal and left central sides of the cortex, while lavender odor causes a significant decrease. Since jasmin is said to have a stimulating effect and lavender is said to have a sedative effect and since taking a nap and drinking a cup of coffee changed the CNV in the same direction as smelling jasmin, an increase in the CNV was interpreted by Torii et al as signaling stimulation and a decrease as signaling relaxation. They then measured the effect on CNV magnitude of 17 additional essential oils, with results that were partially but not fully in accord with the traditional teachings of aroma therapy. In another study,[15]Torii et al applied the same technique to 15 perfume compounds and reported increased CNV for citrus notes and some floral bouquets that were described as happy and excited and lowered CNV for three oriental perfumes, for some lavender-fougères and for sweet and heavy florals.

The interpretation given by Torii et al to their findings was challenged by Lorig and Roberts.[16] While confirming the changes in the CNV reported by Torii et al, they found that similar effects could also be produced by the mere expectation of odor qualities. This clearly suggested that cognitive mediation (such as associations and memories) can be involved in CNV changes. Moreover, noting that in their study lavender had given rise to a high arousal level, they pointed to a report by Tecce et al[17] in which it was argued that CNV is related both to attention and to arousal, and that decreased CNV amplitude, far from indicating relaxation, should be interpreted as distraction from high arousal.

The study on the effects of odors on CNV has been pursued by other researchers in Japan.[18,19,19a,49] Of special interest is the work of Saito et al[13] who decomposed the CNV into nine "basis waves" by means of multivaried analysis of single-trial CNVs. Of these, six occurred during the S1-S2 interval and three after S2. The short-latency waves were affected in the same way both by lemon oil and isovaleric acid, whereas middle- and late-latency basis waves were affected in a different mode according to the character of the odorous stimuli. The authors concluded: "The common mode of effects seems to be attributable to the presentation of odor stimuli, and the different mode of effects to the brain responses induced by odor stimuli."

3.1.3—*Brain waves:* Evoked potentials and contingent negative variation are aspects of the immediate response of the brain to a new, incoming stimulus. Some researchers have concentrated their attention on the effect of odors on the steady state brain waves, those not directly induced by a new stimulus. These steady state waves are known to vary with high sensitivity according to the level of consciousness of the subject. They are distinguished by their frequency. The waves with lowest frequency are called delta waves; those with frequencies of 4-7 Hz are theta waves; alpha waves are in the 8-13 Hz range; and waves with highest frequencies are called beta waves. When engaged in concentrated thought or in highly emotional mental states, beta waves are dominant and alpha waves are inhibited. Alpha waves are dominant in meditation and in other mentally relaxed states. A number of researchers in Japan have explored the effect of different materials on brain wave activity. Sugano[18,19] reported increases in alpha wave activity in the EEG upon presentation of lavender, cineol, sandalwood oil and !a-pinene, and increased beta wave activity upon presentation of jasmin.

Other workers (Yoshida et al[23,24] and Ishitoya[25]) used measurements of frequency fluctuation of alpha wave, measured by power spectral densities at the frontal area of the cortex, and claimed that pleasant odors produced different patterns than offensive odors.

Nakagawa et al[22] found that cineol and methyl jasmonate inhibited the enhancement of alpha and theta waves which appears at the decline of vigilance (presumably a stimulating effect of the odorants); jasmin lactone, on the other hand, enhanced the amount of alpha and theta waves.

Along the same lines, Lorig and Schwartz[20] found more slow wave EEG activity during the administration of a spiced-apple odorant as compared with the administration of lavender and eucalyptus odors. They also found[21] that a number of other odorants tested, most of which were food-related, reduced higher frequency EEG activity. Subsequent experiments by the same group indicated, however, that imagery of food reduced the EEG in a similar way as the food-related stimuli, a finding which strongly points to cognitive mediation of the brain wave changes.

3.2—Physiological Effects

Olfactory-evoked potential, an increase in CNV and a decrease in alpha wave activity are signals of arousing effects of odors. Such effects have also been observed by the use of a number of physiological parameters.

3.2.1—*Systolic blood pressure:* A person given a mild psychological stress typically shows a rising systolic blood pressure. A number of odorant materials, when used in a perfume compound at appropriate levels, have been found to significantly reduce this rise in blood pressure, indicating a stress-counteracting effect.[26] The odorants included nutmeg oil, mace extract, neroli oil, valerian oil, myristicin, elemicin and isoelemicin.

3.2.2—*Microvibration:* Microvibration is described[18] as "a fine tremor seen in warm-blooded animals, ... influenced by muscle tension." According to Sugano and Sato[18,49] the smell of orange and of lavender decreases microvibration frequency and amplitude, indicating relaxation, while jasmin, camomile and musk odor increase these parameters.

3.2.3—*Peripheral vasal constriction:* Physiological stress induces enhanced activity in the sympathetic component of the autonomic nervous system, thereby causing constriction of peripheral vasculature. Thus, the recording of digital plethysmograms can be used as a measure of stress. Konishi et al,[27] using the loud noise of an ultrasonic washing device as a source of stress and a reflection type photoelectric sphygmograph as a measuring instrument, found both peppermint and jasmin to possess stress-relaxation effects.

3.2.4—*Heart rate:* Between the sounding of an alerting buzzer (warning stimulus) and the subsequent sounding of a test buzzer (imperative stimulus), the heart rate is lowered signalling increased alertness. Kikuchi et al[28] explored the effect of odors on this response pattern. Lemon odor enhanced the deceleration, indicating activation of anticipation. This effect tended to be stronger at higher odor concentrations. Rose odor, on the other hand, suppressed deceleration across all concentration levels. Both effects tended to be stronger with those subjects who expressed high preference for the odors. Nagai et al[36] found deceleration suppression by sweet fennel oil.

Oguri et al[29] explored the effects of five unspecified odorants upon both heart rate and the contingent negative variation (CNV). They found that "pleasant odors activating the central nervous system increase the heart rate variations; the sedative odors for the central nervous system decrease them." Moreover, heart rate and CNV tended to vary coincidentally under the same odor conditions. According to the authors, these findings could be explained as effects upon the sympathetic nervous system. Hanisch[68] used heart rate as a measure of fear and found that pleasant commercial fragrances reduced fear.

3.2.5—*Electro-dermal activity (EDA):* The steady current between two points at the skin surface is increased as a result of arousal. Measuring changes in current flow, Steiner[30] ranked 12 test odors (7 essential oils and 5 blends) in order of their arousal effects. The findings did not correspond closely to the CNV results obtained by Torii for the same materials. The correlations between the EDA results and estimates of the activating or calming nature of the 12 odors obtained from the same subjects were 0.50 and -0.64, respectively—significant at the 5% level.

Interesting specific findings in this study included the finding that the EDAs of synthetic rose and jasmin compounds indicated much lower arousal than those of the corresponding natural products. This is important since in many of the reported studies on the effects of rose and jasmin it is not made clear whether the sample employed was natural or synthetic. Since the natural materials are more expensive than the synthetic ones by a factor of 10 to 100, the synthetic may well have been used in some cases.

Steiner's test series included bergamot oil and lavender oil as well as a 2:1 mixture of the two. Interestingly, both in the EDA measurements and in the subjective estimates of activation, the mixture ranked lower than either of the single oils. This points up the danger in assuming additivity of the physiological effects in the case of mixtures.

Hanisch,[68] using skin conductance as a measure of fear arousal, found that pleasant commercial fragrances decreased fear in a stress situation. Parasuraman et al[31] found that periodic 30-second bursts of peppermint during a 40-minute vigilance task increased skin conductance. However, the increase declined over time.

3.2.6—*Skin potential level:* The skin potential is ordinarily about -40 nV upon awakening, rises to -60 nV at times of excitement and drops to almost 0 nV during sleep. Kanamura et al[32] measured the skin potential level at the same time as they determined CNV. They found a slight drop of skin potential during CNV measurements in the absence of odors. This drop was eliminated during exposure to the scent of jasmin and of lavender; it was enhanced during exposure to camomile. The authors interpreted this to show the stimulating effect of jasmin and the sedative effect of camomile. The finding on lavender, being in opposition to the CNV finding, was abnormal.

Niimi[33] found, using SPL tests, that both pleasant and unpleasant odors raise arousal levels, the effect of unpleasant odors being stronger than that of pleasant odors.

3.2.7—*Pupil dilatation/constriction:* Using an infrared television camera, Steiner et al[34] measured the pupil dilation elicited in twelve test subjects by four odor stimuli: rosemary oil (described as "fresh"), bromstyrol ("chemical, unpleasant"), tuberose ("heavy, sweet") and banana. Each stimulus was measured twice, both neat and in 10% solution. The findings included:

- All stimuli elicited pupil enlargement indicating arousal.
- The response magnitude exhibited good intra-individual reproducibility.
- Pupil enlargement was generally less at the second than at the first presentation, suggesting diminishing attention.
- The inter-individual variability was large, resulting in non-significant differences between the group means of the responses to the 2 x 4 stimuli.

The test subjects subsequently verbally described their impressions of the odors, using both a comparison and a polarity profile protocol. Numerical measures of cognitive valuation of "activation," derived from these responses, showed no significant correlation with the pupil dilatation measurements.

Miyazaki et al[35] explored the effects of inhalation of several odorants on the light reflex of the pupil and on performance in a cognitive task (letter cancellation test). They found that orange oil increased the activity of the parasympathetic nervous system (as indicated by accelerating the constriction rate of the pupil) by 12% ($p < 0.05$) and decreased the activity of the sympathetic nervous system (as indicated by the 63% dilatation time of the pupil) by 16% ($p < 0.05$). They noted, moreover, that orange oil, as well as oil of Taiwan Hinoki *(Chamaecyparis obtusa)* and menthol, tended to decrease the error rate in the letter cancellation task.

Nagai et al[36] found that sweet fennel oil reduced the mental stress and fatigue caused by a computerized arithmetic assignment. The effect was significant ($p < 0.05$) in the measurement of heart rate and also ($p < 0.01$) in the pupillary constriction ratio. The effect on a subjective profile of mood state was of marginal significance ($p < 0.1$). The authors interpreted the observed changes as a decrease in the excitation of the parasympathetic nerves.

3.2.8—*Startle-probe reflex:* Ehrlichman and his group[37] measured the startle response to acoustic probes while subjects actively smelled pleasant odors, unpleasant odors or no odor. Generally, the startle reflex is enhanced when the organism is in a negative affective state and reduced when the organism is in a positive affective state. Ehrlichman found the reflex in the presence of the unpleasant stimuli to be significantly enhanced ($p = 0.02$) compared to the mean value for the no-odor condition, and marginally enhanced ($p = 0.09$) compared to the pleasant odor condition. The difference between the pleasant odor and the no-odor condition was not significant. Ehrlichman explained these findings by the hypothesis that unpleasant odors by themselves are enough to generate a negative affective state, but that the generation of a positive affective state by pleasant odors depends on having an appropriate context. An alternative explanation might be that all odors tend to enhance the reflex through enhancing arousal. In the case of unpleasant odors, the effects of arousal and of the negative emotional state are additive; in the case of the pleasant odors, the arousal and the affective component counteract each other.

3.3—Behavior Modification in Laboratory Settings

3.3.1—*Performance in a sustained attention task:* In a test on 36 subjects, Warm, Dember and Parasuraman[38] measured the effects of olfactory stimulation on performance and stress in a demanding and stressful visual attention task. The odors used were muguet and peppermint, administered through modified oxygen masks in the form of periodic 30-second whiffs at 0.13 and 0.05 ppm, respectively. In a prior independent test, both fragrances had been judged to be hedonically pleasing, with muguet rated as relaxing and peppermint as alerting. Both fragrances were found significantly ($p = 0.05$) to improve performance in the test, with no difference in effectiveness between the two. Neither of the fragrances had a significant effect on subjective experience of stress or of work load.

Subsequent studies by the same group yielded additional insights. In replication experiments with peppermint, it was found that performance was improved only among those subjects who reported that they had become inattentive as the vigil progressed; it had no effect upon those who reported high levels of attentiveness even at the end of the task.[38a] In an experiment in which subjects delivered scented (peppermint or muguet) or unscented (control group) air to themselves ad lib by pressing a button which released an 8-second burst of air, both peppermint and muguet improved performance accuracy, but only for the female subjects.[39] In another experiment, using only peppermint and unscented air, the vigilance performance of young (college-age) subjects was improved by fragrance, but that of elderly subjects was not.[39] In another, peppermint again enhanced performance; recordings of galvanic skin response and of visual evoked potentials taken from the skull were made concurrently with measures of performance.[31] Peppermint increased overall skin conductance levels, suggesting an increase in autonomic arousal. However, both the peppermint and the air control groups showed parallel declines in skin conductance over time. In contrast, while the amplitude of the N 160 component of the event-related brain potential (ERP) decreased significantly over time for the control group (no odor), it remained relatively stable for the peppermint group. The N 160 component has been linked to efficiency in allocating attention to relevant visual signals. Taken together, the skin conductance and ERP findings suggest, therefore, that the performance improvement was due to positive effects of peppermint on attention allocation over time rather than to the arousal-increasing effect of the odor.

3.3.2—*Reaction time in a sustained attention task:* Using ten subjects, Karamat et al[40] found that lavender oil, administered on a surgical mask, significantly increased decision time in a computer-based reaction time task, both without and with a warning tone; it did, however, not influence motor time. This was interpreted as indicating that lavender oil has a central but not a peripheral sedative effect. A second experiment[40] by the same group involved choice reaction time in a vigilance task with 24 subjects. Here again, lavender oil caused significant increases in reaction time, while jasmin absolute caused a significant decrease.

3.3.3—*Sleep latency:* Dember and his group conducted a study on the effects of peppermint and muguet on sleep latency and performance of some very brief tasks.[39] Subjects in a sleep disorders clinic were awakened at two points during the night and early morning, given whiffs of fragrance or air while doing some simple performance and cognitive tasks, and then permitted to go back to sleep. The time it takes to fall asleep (sleep latency) is a standard measure used to assess the soporific properties of drugs. If the fragrances served as CNS arousers, or anti-soporifics, sleep latency should have been increased in their presence. The results failed to support that hypothesis, and the fragrances also did not improve task performance.

Miyake et al[41] explored the effect of six essential oils (spike lavender, sweet fennel, bitter orange, linden, valerian and marjoram) on sleep latency under stress conditions. Stress was created by requiring the subjects to conduct 300 calculations over a 10-minute period. Sleep latency was evaluated from brain waves using a standardized scoring system and computer analysis of components of the 4-14 Hz waves. Bitter orange reduced sleep latency. This was interpreted as an inhibition of the excitement of the central nervous system.

3.3.4—*Learning and recall:* Frank and Ludvigh[42] presented 15 subjects with a learning task (nonsense syllables) and subsequently with a group of six odors which the subjects compared and rated in terms of pleasantness. The subjects were then tested for recall of the learned syllables. This type of test was repeated three more times, all within a two-hour time span. In the first and last part of the experiment, the six odors had been selected to be hedonically indifferent; in the second and third part, six pleasant or six unpleasant odors were presented. The results showed a *retroactive* facilitating effect on learning for the pleasant odors and a retroactive inhibiting effect for the unpleasant odors.

An experiment with 76 subjects explored the effect of ambient odors, presented at subliminal levels without the subjects' knowledge, on a number of evaluative and behavioral measures. In this experiment Steiner[43] included a test of the recall of print advertising. He found that in the presence of a room fragrance which the same test subjects had rated significantly positive both on arousal and on mood effects, recall was significantly improved. Another fragrance, which had also rated positive on arousal but negative on mood effects, caused no change in recall.

A further study on the effect of ambient odors on memory was conducted by Ludvigson and Rottman, using 72 test subjects and oil of lavender and clove oil as the stimuli.[44] No improvement of recall was detected in this case, even though according to earlier literature data, the two fragrances selected were generally deemed pleasant. The major difference with Frank and Ludvigh and Steiner's tests appears to have been that the ambient odors were here presented at "subjectively quite strong" levels. Questions posed regarding the general attitude towards the test indicated a favorable shift caused by lavender (compared to the no-odor control) in the first but not in the second of two test sessions; the feeling about the clove odor tended toward the negative in both sessions.

In a test on 77 primary school children aged 7 to 10 years, Berg[45] investigated the effect of odors on the recall of a word list, immediately as well as after one and two weeks. The odors, eucalyptus oil, lemon oil or an orris base, were presented on absorbent paper and sniffed directly by the test subjects. Each child was given the odor that he or she had liked best among the three. The findings indicated that recall was facilitated when odor was presented at either stage (during learning or during recall), but the best results were obtained when the odor was presented at both stages.

3.3.5—*Memory retrieval:* Ehrlichman and Halpern[46] found that people smelling a pleasant odor recalled more happy memories from their pasts as compared to people smelling an unpleasant odor.

3.3.6—*Creative task solving:* Ehrlichman and Bastone[47] measured the performance of 86 subjects in a remote associates test (RAT) while the subjects were smelling one of two pleasant odors (almond extract or muguet), or one of two unpleasant odors (butyric acid or thiophene) or were not exposed to any odor (control group). The RAT requires that subjects see relatedness in words that normally appear to be unrelated. Previous research had demonstrated that positive moods resulted in better performance on these kinds of items; prior evidence linking negative mood effect to creativity was inconclusive. The test showed that for the moderately difficult RAT items, correct response rates were considerably higher for the pleasant odor group than for the unpleasant odor group ($p < 0.05$); neither group, however, differed significantly from the no-odor group. There was no odor effect upon the response to the easy RAT issues.

Knasko[48] explored the effect of three environmental odors (lemon and lavender at subliminal levels, dimethyl sulfide at a noticeable level) on performance in the figural Torrance test of creative thinking. She found no significant effect of odor.

Sugano and Sato[49] explored the effects of lavender, rose, orange, jasmin, eucalyptus, camomile and musk on efficiency in a computer-aided calculation task and also on micro-vibration and on the contingent negative variation (CNV). They found that orange, rose and lavender increased the alpha band of micro-vibration and inhibited the CNV, suggesting mental relaxation. Jasmin, camomile and musk, on the other hand, augmented the beta band of micro-vibration and increased the CNV, suggesting mental stimulation. Interestingly, work efficiency as measured by mean reaction time was increased by orange, rose and lavender. The authors remarked, however, that "the effects of fragrances were quite different from person to person."

3.3.7—*Evaluation of ambiguous stimuli:* In an experiment with 25 male subjects, Steiner[50] investigated the effect of an unspecified ambient fragrance upon the perception of ambiguous visual stimuli. The stimuli were created by superimposing upon each other, at varying intensities, a picture of a city skyline and a picture of a woman. After being exposed to 1/200 second flashes of each slide, the test subjects had to indicate whether they had just seen a city or a woman. Nearly all test subjects gave higher rates of "woman" responses in the presence of the fragrance than under the control condition. The difference was most pronounced with those slides in which the image of the skyline and the woman were about equally strong.

Steiner[43] found two room fragrances to have no significant effect upon the evaluation of cigarette and liquor ads or of photographs of landscapes and of people in social and solitary situations. The ratings of a list of items such as "videophone," "meditation," "bowling," "art gallery" were also not significantly affected by the fragrances.

Ehrlichman and Bastone[47] analyzed the ratings given by 35 subjects to two sets of 12 men's and women's faces and to a set of 12 words (all chosen because they had received relatively neutral ratings in prior tests). When the test subjects were exposed to a pleasant odor (almond extract) or an unpleasant odor (thiophene), the ratings of the photos on "personality" were significantly more positive in the presence of the pleasant odors than in the presence of the unpleasant odors; this finding, however, held only for those subjects who were highly "field dependent." Field dependence, as measured by the Rod and Frame Test (RFT),[51] is a personality variable: field dependent people tend to rely on information as given and to be guided in their responses by contextual cues; field independent people actively restructure information and rely on internal frames of reference. On the rating of the neutral words, the highly field-dependent respondents gave marginally higher positive ratings in the presence of the pleasant odor than in the presence of the unpleasant odor ($p = 0.07$).

In a similar experiment, Cann and Ross[52] compared men's rating of attractiveness of slides of women in the presence of a pleasant odor (spray cologne), unpleasant odor (ammonium sulfide) or no odor. The odor condition did not affect attractiveness ratings. This may have been due to the fact that the stimuli were chosen to represent relatively attractive and unattractive women; it is reasonable to believe that odors can influence responses to ambiguous or neutral stimuli, but not to clearly positive or negative ones.

3.3.8—*Miscellaneous cognitive tasks:* Ehrlichman and Bastone[47] tested the effect of exposure to pleasant odors, unpleasant odors or to no odor upon subjects' performance in a questionnaire measuring optimism about risk and likelihood of positive/negative events, and also in a test of associations to situations in which helping might occur. Odor was not found to have a significant effect upon either of these test measures.

Thompson and Lorig[7] examined the effect of two odors, peppermint and vanilla, on the estimation of the passage of 60 seconds. Generally, increased arousal speeds subjective estimates of time passed. The results of the study demonstrated that peppermint decreased estimates compared to the no-odor control, suggesting increased arousal. Vanilla also decreased the estimates, but only in females; in males, it increased time estimates. The reason for this sex-specific differential effect for vanilla is unknown.

Baron[53] examined test subjects' performance in a negotiation task between same-sex confederates in the presence of a pleasant ambient odor, and compared that with the same situation in an unscented room. He found that the subjects in the scented room set higher monetary goals, were less confrontational and more likely to make concessions than were subjects in the unscented room.

Rotton[54] found that a malodor impaired college students' performance on a complex (proofreading) task, but not a simple (arithmetic) task. He also found that the negative effects of the malodor persisted even after leaving the unpleasant smelling room, especially when the exposure was prolonged and unavoidable.

Knasko[55] measured the effects of intermittent bursts of pleasant (lemon and ylang ylang), unpleasant (isovaleric acid and skatol) and no experimental odor on performance in simple and moderately complex mathematical and verbal tasks. The odor levels were such that their pleasantness or unpleasantness was consciously perceived by the subjects. Although the odors did not objectively influence performance, subjects who had been exposed to the malodors retrospectively *believed* that the room odor had negatively affected their performance. They also believed that the room odor had had a negative effect on their mood and health, although mood and health related ratings obtained during the actual sessions showed no difference due to odor.

3.4—Odors and Sleep

An extended study on the effects of fragrances on the quality of sleep was conducted by Badia and his group with the support of the Fragrance Research Fund/Olfactory Research Fund. Using changes in heart rate, brain waves and muscle tension as objective measures, Badia showed that people are responsive to odors in sleep. In addition, if instructed, prior to sleep, to press a hand-held switch and to awaken if they detected an odor, individuals on many occasions were able to do so. As expected, the probability of these changes occuring increases with stronger odor concentration. When odors are presented during REM (dream) sleep, individuals often incorporate these stimuli into their dream.

Badia et al[56] found that jasmin, peppermint and coumarin all were disruptive to sleep. Heliotropine, which in early research appeared to facilitate sleep, was later found to have neither disruptive nor facilitating effects.[57] A very interesting finding in a subsequent study was that androstenone, a key component of human body odor, had a far stronger disruptive effect than any of the other odorants.[58] This effect was found even among subjects who were unable to detect the odor in the waking state (some 33% of the participants in Badia's study were anosmic to androstenone). Androstenone is often described as a musky odor. A test was, therefore, conducted to establish whether a synthetic musk odor, Galaxolide, would have similar effects. Galaxolide had been shown to be disruptive to performance during waking.[59] It was, however, found not to be disruptive to sleep.[60]

Two studies assessed the effects of androstenone, peppermint and lavandin grosso on dream content, dream affect and EEG activity. The studies showed differential effects on EEG, rare incorporation of odors into dreams and minimal effect on the emotionality of dream.[58,60] The effects of androstenone on sleep were the same irrespective of whether the subjects judged the odor as pleasant or unpleasant.

A rather different response pattern was reported by Willer et al[61] from a pilot study in which seven young males served as test subjects. Orange oil caused a significant increase in heart frequency and respiration rate, and a positive effect on dream content. Skatol, a material with a highly unpleasant, fecal odor, generated a slight increase in heart rate and extremely negative dream contents. Female axillary and vaginal secretion generated individually different physiological responses, but highly positive effects on dream content.

3.5—Behavior Modification in Real-Life Settings

3.5.1—*Shopping behavior:* Teerling et al[62] injected two ambient fragrances into the air conditioning system of textile department stores at pulse frequencies that resulted in odor levels around threshold, and found that "ambient odor can be highly effective in increasing the time customers spend in shops." The fact that the three conditions (two odors, one control) were assigned to one store each, in different cities, precluded rigorous statistical analysis. Sales figures were down 2.89% compared to the same period in the preceding year in the store under the no-fragrance condition; they were down only 1.22% under the fragrance conditions. Threshold fragrance levels had been chosen because earlier experiments had indicated that only at this level do odors have an effect on people's behavior.

Knasko[63] introduced a fruity/floral scent and a spicy scent into a jewelry store and found that people lingered longer, though they did not buy more. The fruity/floral scent increased the lingering time of both women and men, the spicy scent affected men only.

Applying both pleasant and unpleasant, congruent and incongruent odors at a museum exhibit, Knasko reported that the odors affected lingering time, mood and feeling about the exhibition, in rather complex patterns.[64]

3.5.2—*Gambling:* Hirsch[65] reported that an aroma used to odorize a site in a gambling casino increased the amount of money gambled in the slot machines surrounding that site by 45.11% ($p < 0.0001$) compared to non-odorized control areas. The test was run on two successive days. On day 1, aroma concentration was higher and the increase was 53.42%; on day 2, with lower aroma concentration, it was 33.66%. Another aroma tested in the same manner had no effect on gambling rate. Neither the nature of the aromas used nor their concentration was disclosed.

3.6—Direct Measurements of Mood/Emotion Changes

3.6.1—*Reduction of stress and anxiety:* Redd and Manne[66] administered periodic low-intensity whiffs of heliotropin (on a 30-second "on," 60-second "off" cycle) to 85 patients during magnetic resonance imaging for diagnostic work-up for cancer. Heliotropin had been selected from among five fragrances because it had been rated most relaxing and most pleasant in a pretest. The respondents indicated their anxiety level pre-, during and post-treatment on a line scale and by completion of the State-Trait Anxiety Inventory. Statistical analysis of 55 subjects' responses (20 fragrance, 35 control) indicated a reduction of anxiety during the scan which was marginally significant ($p = 0.06$) for the entire fragrance group, but significant ($p = 0.02$) for those respondents ($n = 12$) who found the fragrance very pleasant and also (p = 0.02) for those (n = 12) who found it very relaxing. The 16 subjects from the fragrance group who did not detect the scent, and 12 subjects who did not report any anxiety prior to the scan, were excluded from analysis.

In a subsequent study,[67] Manne and Redd explored the effect of wintergreen fragrance under the same conditions. Although wintergreen was rated as pleasant by the majority of patients, it did not cause a significant reduction in patient anxiety, probably because it was assessed as invigorating rather than relaxing.

Warren et al[26] induced moderate stress by demanding quick responses to such statements as "The thing I like least about myself is ...." The stress was measured by systolic blood pressure and by a self-administered questionnaire in which respondents indicated their degree of relaxation, anger, anxiety, happiness, tenseness, embarassment, calmness, fear and sleepiness on a 7-point scale. A number of active odorants (including nutmeg oil, mace extract, neroli oil, valerian oil, myristicin, elemicin and isoelemicin) was found to significantly increase happiness and calmness and to decrease embarassment and anger when administered either alone or incorporated into a complex fragrance. These findings paralleled the measurements on systolic blood pressure taken in the same experiment.

Hanisch[68] measured the effect of fragrance on the fear evoked in 24 young spider-aversive females by a prepared spider suspended at a short distance from the subject's face. Four measurements were taken in parallel: self-reports of anxiety level on a 0-100 scale, electrical skin resistance, heart rate and a behavioral measure indicating the closest subjectively tolerable spider-to-face distance. The fragrances (1 per subject) were self-selected by the subjects from among 24 commercial perfumes according to the criteria of pleasantness and non-familiarity. The fragrances were found to significantly reduce fear on all measures under both of two test conditions. In one, the subjects had been instructed to smell the selected fragrance over a several-week period whenever they felt particularly good (self-conditioning); in the other, there was no prior self-conditioning.

3.6.2—*Various mood changes:* Steiner[43] asked 76 volunteers, in the course of a multi-task experiment, to record their mood using a 123-item adjective list. The test was conducted under two experimental conditions. In one, unspecified space fragrances A or B were presented in the test room at subliminal levels. The other was a no-odor control condition. In the presence of test fragrance A, subjects recorded their mood as being significantly higher in "high spirits," "extroverted feelings" and "arousal" and lower in "despondency" and "introverted feelings" compared to the subjects in the control condition. Fragrance B also increased "arousal," but also "despondency," "introversion," "lethargy" and "dreaminess" while it decreased "high spirits" and "self-confidence. "

Knasko[48] also conducted a multiple-task experiment involving 90 subjects in a testing room scented with lemon, lavender or dimethyl sulfide at weak-to-moderate levels; control sessions were conducted in the same room with no odor applied. The test included completion of a Semantic Differential Measures of Emotional State questionnaire consisting of 18 scales which measured pleasure, arousal and control. Lavender oil (38/40) and lemon oil Californian FCF caused no significant change in pleasure; with dimethyl sulfide, this measure was significantly depressed. None of the odors significantly affected "arousal" or "control."

Knasko's experiment also strikingly revealed the effect of expectation upon odor perception. For each of the odorants, the odor and the no-odor conditions were presented to the same subjects one week apart, both in this order (order 1) and in the reverse order (order 2). The subjects who had been exposed to dimethyl sulfide in the first smelling session, and who, like all other test subjects, had been made generally aware of the issue of room odor by a question at the end of the test session, gave extremely low ratings on the pleasure scale in the *second* test session, even though there was objectively no odor in the room during that session. The average pleasure rating in session 2 for this group was, in fact, significantly lower than the rating in session 1 when dimethyl sulfide was actually present, but, presumably, many subjects had not been consciously aware of it when completing the mood questionnaire.

Warren and Warrenburg[69] measured mood changes induced by overt presentation of five pleasant "living flower" fragrances to 35-50 women, and found that the fragrances elicited, to varying degrees, increases in happiness, sensuality, relaxation and stimulation and decreases in irritation, stress, depression and apathy. An interesting aspect of their report was that relaxation and stimulation are not necessarily opposed in a subjective sense: the muguet and the hyacinth fragrance both caused increases on both measures.

In an experiment conducted by Kirk-Smith and Booth,[70] young male and female adults (16 subjects per odorant) smelled a low concentration of a short-chain fatty acid mixture, androstenone, 1-pyrroline, "Shalimar" perfume or a control odorant (banana essence) and rated their mood states and attitudes and those of men and women in photographs. These ratings were compared with those in counterbalanced sessions without odorant. The subjects did not report awareness of the presence of the odorant during the experiment. Shalimar made assessors rate themselves more sexy and outward-going, 1-pyrroline made them feel more sociable, androstenone stronger, fatty acids more excited and banana essence made them less friendly. All of the odorants selected, with the exception of banana essence, are presumed to be relevant in a sexual context.

Baron[71] found sex-specific effectiveness of pleasant perfumes in reducing aggressiveness.

Ehrlichman and Bastone,[47] presenting a pleasant odor (mint, orange, almond or chocolate), an unpleasant odor (pyrridine) or no odor (water) to 45 women via a surgical mask, asked the respondents to rate their current mood. The pleasant and the unpleasant odor groups differed significantly from each other in their ratings of both "good" and "bad" mood, but neither group differed significantly from the no odor group on these measures.

Bastone and Ehrlichman[47] assessed self-reported mood during a series of experiments in which subjects smelled almond or muguet, thiophene or butyric acid, or no odor. Subjects described their "current state" on five mood-related scales (sleepy-alert, annoyed-pleased, depressed-excited, tense-relaxed and disgusted-delighted) at 1 minute, 14 minutes and 28 minutes after the presentation of the odor. They found significant odor-related changes on the annoyed-pleased, disgusted-delighted and tense-relaxed scales. An interesting aspect of their findings was that the positive effects of the pleasant odors had decreased after 14 minutes and completely subsided after 28 minutes, while the negative effects of the unpleasant odors remained in full force throughout the test. The researchers suggest that one reason for the observed pattern may be the tendency of pleasant odors to habituate more strongly over the course of the study than the unpleasant odors.

An experiment conducted by Knasko[72] involved viewing and judging of photographic slides in a room scented with a chocolate scent, a baby powder scent or no scent; viewing times were measured as well as mood and health-related attitudes. More subjects were in a positive mood in the odor conditions than in the no-odor condition. Subjects in the odor conditions also rated the room as smelling more pleasant and reported being less fatigued. Subjects in the chocolate condition were more aroused than those in the other two conditions.

In all of these studies, the subjects were passively exposed to fragrances or malodors in a controlled setting. A very different type of experiment was conducted by Schiffman,[73,74] who studied the mood effects upon women and men at mid-life of actually wearing a cologne, selected by the respondent, under real-life conditions.

The women's test panel[73] consisted of 56 women aged 45-60, both pre- and post-menopausal. They selected from among five perfumes the one or ones which they preferred and used these for five days, completing a Profile of Mood States (POMS) questionnaire twice daily; in a five-day control condition, they used an odorless spray in place of any fragrance. The fragrances were presented in glass containers labelled "A" through "E"; the placebo resembled the colognes in appearance and was labelled "F". The fragrances were found to effect significant ($p < 0.05$) improvements on the total mood disturbance score and also on all of its individual factors: tension, depression, anger, vigor, fatigue and confusion. The effect of fragrance was comparable for the African-American and the European-American respondent groups with the exception of the factor "vigor" where the effect was more clear-cut with the European-Americans. The odorless placebo sample as well brought about significant positive changes on total mood disturbance and several individual factors, but the effect of the fragrance samples was significantly ($p < 0.05$) stronger than that of the placebo. Those women who liked the fragrance(s) they selected (82%) showed significant improvement of the total mood disturbance score as well as on the tension-anxiety and fatigue-inertia factors. Even with non-liked fragrances and with the odorless placebo, there was a (statistically non-significant) trend toward improved mood. The physiological menopausal symptoms were, in the perception of the test subjects, not improved by the use of fragrance.

The parallel study on men[74] (60 subjects, aged 40-55) also showed significant improvement by colognes of all POMS including tension, depression, anger, vigor, fatigue, and confusion, as well as for the total mood disturbance score. The placebo condition (odorless cologne) again showed significant improvement compared to the no-cologne condition, but again, the scores for the fragrance condition were significantly better than those for the placebo condition, for all factors and for the total mood disturbance score.

The positive effects achieved in Schiffman's experiment even by odorless colognes (alcohol only) demonstrate the possible role of auto-suggestion in the fragrance experience. This effect was also impressively shown in an experiment conducted by Knasko et al.[75] Subjects completed questionnaires and cognitive tasks in a constant, odor-controlled environment. The experimentor suggested the presence of positive, negative or neutral odors in the room, indicating that some people may not smell the odor. The suggestion of a hedonically positive odor increased self-reports of pleasantness and positive mood.

3.6.3—*Effects on perceived health:* Knasko et al[75] found that subjects were likely to report more negative health symptoms when told that there was a malodor present in the environment than when they were told that there was a pleasant or neutral odor, even when in reality there was no difference in the ambient odor. In a subsequent experiment,[48] Knasko assessed health reports when odors were actually present at low to moderate levels. She found that the presence of a lemon odor significantly reduced reported health-impairment symptoms while dimethyl sulfide non-significantly increased them.

3.6.4—*Conditioned mood changes:* It has been suggested that the emotional qualities of odors are individually learned as a result of the context in which they were first encountered.[76] Curiously, we have found only one study that directly explored this question. Kirk-Smith et al[77] exposed six male and six female subjects to a faint unfamiliar hedonically neutral odor while performing a stressful task. The test subjects were unaware of the odor's presence. A matched control group performed the same task with no odor present. Subjective mood states were evaluated several days later in the presence of low concentrations of the same odor. Female subjects in the experimental groups gave significantly higher anxiety ratings than the other groups; they also projected this anxiety onto their judgement of photographs of others. None of the subjects reported perceiving the odor in either session. The fact that no significant mood effects occurred in the male subjects may have been due to the fact that the males, who performed significantly better in the task than did the females, did not find it stressful.

4. Discussion

Aroma-Chology is a young discipline. The picture that emerges from the tour d'horizon offered in the preceding pages is complex, confusing and in part contradictory. In the discussion that follows, we shall examine what appear to us to be key issues emerging from the current literature, and attempt to summarize the available evidence.

4.1—Primacy of Hedonics

Ehrlichman and Bastone[47] state that the "core experience [of affective states] is what psychologists have called hedonic valence, feelings of pleasure or displeasure which form a sort of primitive experimental matrix from which all ... affective or emotional states emerge." Kobal and Hummel[11] have found evidence that the categorization of odor stimuli into pleasant or unpleasant occurs in the very early phases of the evoked response and affects the patterns of everything that comes later, such as the cognitive processing of the stimulus.

A number of research studies, starting with the pioneering study of Frank and Ludvig,[40] showed that the pleasantness or the unpleasantness of the odor stimulus has significant effects upon the startle reflex,[37] upon mood,[45,48] relaxation and stimulation,[28] evoked memories,[46] learning and recall,[42,43] sustained attention[39] and reported health symptoms.[75] In many studies, the importance of pleasantness was taken for granted and the stimuli used were preselected for pleasantness.

There is evidence that the effects of pleasant and unpleasant stimuli differ not only in quality, but also in duration. Ehrlichman and Bastone[47] observed this difference looking at a 28-minute time span. Their finding may be explained by postulating that habituation to unpleasant odors is less than to pleasant ones. Indeed, Ehrlichman and Bastone found that intensity and pleasantness ratings of the pleasant stimulus decreased over the time period studied while they stayed constant for the unpleasant stimulus.

Rotton[54] found evidence for lingering after-effects of malodor exposure upon attitudes. Knasko[48] reported a significant after-effect (after one week) upon mood ratings of the exposure to a malodor, but no long-term effects with two more pleasant odors. A generalized conclusion that unpleasant odor experiences are stored more effectively in long-term memory than pleasant ones is probably not warranted. Such a conclusion would be in conflict with established opinion regarding the "Proust" effect (the lifelong persistence of certain odor memories, both pleasant and unpleasant) and also with the report[45] of long-term effects on pleasing odors on learning and recall. An alternative explanation would be that the conditioned coupling of the test room with the odor expectation is stronger in the case of malodors than with more pleasant ones.

Three practical conclusions can be drawn from the link between hedonics and Aroma-Chology effects:

1. Where positive effects upon mood or performance are desired, it is a good idea to select odor stimuli and odor concentrations that are considered pleasant by the target group.

2. In spite of Kobal's indication that the categorization of hydrogen sulfide and vanilla into unpleasant/pleasant occurred at a subcortical level, experience shows that many hedonic judgements are culturally based or the result of individual learning experiences.[76] We must expect, therefore, that many Aroma-Chology effects are not universal, but subject to individual variation, and that they may be specific to certain cultures.

3. The perception of odor blends is pattern or "Gestalt" perception, and the hedonic quality of such blends is not the weighted sum of the pleasantness or unpleasantness of its components. Vanillin, to give but one example, generally achieves high hedonic ratings, yet the addition of vanillin to an essential oil or to a blend does not necessarily improve the hedonic quality and may, in fact, well lower it.

To the extent that fragrance effects on moods, emotions and performance are related to hedonic quality we must therefore expect the effects of blends to be subject to the laws of pattern or "Gestalt" psychology rather than being a simple weighted sum of the effects of their components. It may appear reasonable to argue: "Fragrance X contains material Y which has been proven to produce effect Z. Therefore, fragrance X produces effect Z." However, to the extent that likes and dislikes are involved in the production of the effect, such arguments are questionable. Statements about blends can be made only on the basis of tests involving the complete blends.

The only published experimental evidence regarding this question is in Steiner's study.[30] Here, a blend of 66% bergamot oil and 34% lavender oil was found to be less activating than either of its components. Synthetic jasmin and rose compositions were less activating than their natural counterparts even though presumably the chemical compositions of the synthetic and natural blends were similar in both cases. The statistical significance of Steiner's findings is hard to assess. It would certainly be desirable to test this fundamental question more thoroughly.

4.2—Cognitive and Non-Cognitive Mechanisms

Lorig[7] has proposed to distinguish between *direct* and *indirect* odor effects: "Indirect odor effects refer to those central nervous system changes resulting from cognitive activity related to the information conveyed by the odor. Direct effects are non-cognitive in nature and are due to direct stimulation of the olfactory tract and other related brain structures, but do not include the subsequent neurophysiological activity associated with the cognitive processing of odors." This distinction is fundamental, not only from a conceptual point of view but also in its practical consequences.

Several of the studies cited in this review strongly suggest the involvement of cognitive activity in the form of expectations[16,21,75] or the learned pairing of odors and situations.[48,77] In other cases, observations could be explained by learned pairings. The anxiety-relieving effect and the absence of sleep disturbance effects of heliotropin were both observed in experiments conducted in the U.S.A. The odor of heliotropin is reminiscent of that of the Johnson & Johnson baby products which have been widely used in the U.S.A. for several generations, and of many other baby products in the U.S. market. Are the effects of heliotropin related to unconscious associations with care and protection experienced as a baby?

On the other hand, Kobal's work on the left and right half of the brain and their responses to pleasant and unpleasant odors[11] points to pre-cognitive categorization, that is, a direct mechanism. It demonstrates, at the same time, the extreme sophistication of experimental method required for a valid distinction between cognitive and pre-cognitive effects.

On the basis of the available evidence and in view of the ubiquitous social learning of odor meanings, I believe that careful interpretation of experimental findings requires one to take the possibility of cognitive mediation (indirect mechanisms) into account in all cases where it is not demonstrably excluded. As the study by Kirk-Smith et al[77] has shown, cognitive processing is possible even in cases where there is no conscious awareness of an odor. We must be careful with statements of the form "jasmin is stimulating" or "lavender is sedative" which imply universality and hence independence from individual learning experiences, particularly if we base them on experiments involving a small number of subjects or subjects who all belong to one culture.

The point regarding "Gestalt" perception of blends which was raised above is equally pertinent to cognitive aspects of odor processing such as the assignment of learned meanings to odors. The possibility of cognitive mediation is another reason for refraining from drawing conclusions about the effect of mixtures based upon the effects of components.

4.3—The Need for Precise Definition of Stimuli and Effects

Torii et al[14] using the contingent negative variation (CNV), Sugano[18] measuring alpha wave activity in the EEG and microvibration, and Karamat et al[40] using decision time, found lavender to be relaxing or sedating and jasmin to be stimulating. Torii could not confirm the relaxing effect of lavender in his measurements of skin potential[32] and Karamat et al[40] found lavender to have no effect on reaction time. Konishi et al,[27] using peripheral vasal constriction as an indicator, found jasmin to be stress-relaxing rather than stimulating. Steiner,[30] using electrodermal activity measurements, found natural jasmin absolute and lavender oil 40/42 to be equal on the activation scale; when he measured activation by overt respondent estimation, lavender was judged to be far more activating than jasmin.

The most likely explanation for this confusing picture and for other contradictions in the literature is that the presentation of an odor stimulus triggers a cascade of events in the brain and the nervous system, and this cascade is too complex to be covered by simple terms such as arousal or activation, relaxation or sedation. Depending on where the measurement technique taps into the process, different effects are found. The technique of Saito et al,[13] who resolve the CNV into basis waves and find undifferentiated effects of odors in the short latency and differentiated response in the middle and late waves, exemplifies the precise analytical approach needed here.

In addition, the method of presentation of the stimulus (Is the subject aware of its presence? Does he or she know its nature?) is likely to affect the results, as is its concentration. The latter point, well-known to perfumers, has rarely been systematically addressed in Aroma-Chology literature.

Finally, the precise nature of the odor stimulus may well play a larger role than many experimenters realize. There are many different grades of lavender oil, and they may well differ with respect to their activation/relaxation potential. In the case of jasmin, Steiner[30] found pronounced differences between jasmin absolute and a synthetic jasmin composition in terms of electrodermal activity (natural jasmin being more activating) although not in the subjective estimation of the test subjects. The presumption is that all researchers used natural jasmin absolute. But since the natural, at about $5000 per kilogram, is 10-100 times as expensive as synthetic jasmins, this is not necessarily the case—especially since not all jasmin absolutes that are sold as natural are as pure as they should be. At any rate, Steiner's findings (which were, incidentally, paralleled by his findings on natural rose oil and a rose composition) should caution us against using phrases such as "the stimulating effect of jasmin" in a loose, uncritical manner.

4.4—Essential Oils, Aroma Chemicals, Fragrance Blends

Classical aroma therapy ascribes special virtues to natural essential oils and works predominantly with these oils. Much of the recent research conducted in Japan, seeking to establish a scientific basis for the traditional art, also focuses on the effects of essential oils and of their components. In the U.S.A. and in Europe, the selection of stimuli has been far more eclectic, and essential oils, single aroma chemicals (largely synthetic in origin) and fragrance blends (usually containing a multitude of natural and synthetic materials, the latter dominating in quantity) have been tested side by side, in mixed arrays.

There is no evidence of any general or fundamental difference between the different categories of stimuli with respect to their Aroma-Chology effects.

4.5—Aroma-Chology and Aroma Therapy

In spite of all of the differences between Aroma-Chology and aroma therapy enumerated at the beginning of this article, there is an area of overlap. The essential oils used by aromatherapists have been among the materials investigated in recent Aroma-Chology research. The Japanese workers in the field have, in fact, concentrated upon these essential oils. The aims of Aroma-Chology, short-term changes in psychological state or cognitive performance, have been among the aims of traditional aroma therapy. At least since the Renaissance, plant distillates have been used for such purposes as brightening the mood, sharpening the mind or aiding memory. Has the recent Aroma-Chology research confirmed or disproved the old claims of aroma therapy in this area?

A dispassionate look at the evidence leads to the conclusion that aroma therapy's attributions of facts have been verified in several instances, but to a rather restricted degree. Statements such as "peppermint strengthens the brain"[78] must, in the light of experiments of Dember et al,[38,38a,39] be restated to read "under certain conditions, peppermint strengthens the brain of some people." Careful experimental methods that remove or neutralize distracting variables, especially such as may lead to specific expectations, are necessary lest these variables overshadow the effects of the agents that are being studied. The traditional claims of aroma therapy appear to rest on a slender basis.

There is, however, an alternative way to look at the situation. The removal of interfering variables, a necessity in the contemporary scientific tradition in which Aroma-Chology is embedded, is foreign to the tradition of aroma therapy. In fact, aroma therapy actively seeks to introduce such variables. Its approach is wholistic. The "active agent" is only part of a treatment which includes the total atmosphere of the therapist's practice, physical stimuli such as massage and, above all, the therapist's authority and his or her personal attention to the person that is seeking help. Tisserand[79] acknowledges that "low doses seem to require the potentiating or synergistic aid of additional factors" such as "counselling with visualization, massage and the domestic bath" and that "no matter which essential oils are used in treatment, there is invariably an improvement in mood and temperament." Investigations in the field of placebo effects have shown the power of expectation, all by itself, to generate measurable psychological and physiological effects. The findings of Lorig and Roberts[16] and of Knasko et al,[75] indicating that mere suggestion can lead to distinct changes in brain electrical activity patterns or in perceived state of health, become positive if seen in the perspective of a wholistic rather than an analytical approach. Schiffman's finding[73,74] that regular use of plain alcohol as though it were a perfume produced a similar morale-boosting effect, albeit weaker, than the use of real perfume, points in the same direction. If significant placebo effects can be achieved in the absence of any active agent, it is reasonable to believe that even more robust effects can be obtained by the combination of agents that are active, however weakly, with auxiliary supporting factors such as the authority of the healer or information about the age-old use of the active agent.

Where does this leave the products with mood-modifying or performance-improving claims that are currently sold at retail or dispersed in the air of hotel lobbies and hospitals, offices and retail stores? Claims that such products generate a feeling of well-being among people who like the fragrance are well founded; so much so, in fact, that they may create the marketing problem of being perhaps too obvious. Claims for more specific effects such as activation, performance improvement or stress relief, are not *proven* by whatever reports exist in the aroma therapy literature about such effects. Where proof in the modern scientific sense is needed, it can be supplied only by the analytical and objective methods demanded by Aroma-Chology. Nevertheless, reference to such aroma therapy use may be helpful as a confidence building measure, that is, to boost the product's effectiveness through creating a favorable set of expectations.

In current practice of developing and marketing mood-effective personal or environmental products, we find a side-by-side use of aspects of the wholistic approach of aroma therapy and the analytical approach of Aroma-Chology. The analytical approach is used by the development departments to establish the justification of claims; the wholistic approach is used by marketing to communicate the product's purpose to the consumer and to enlist the supportive cognitive mechanisms which boost the product's effectiveness. One may take exception to this intertwining of fundamentally different perspectives, but it is standard practice in many fields including, for example, medicine. It is, in fact, the best way we have today of developing and marketing products that are both effective and successful.

4.6—Characteristics of the Subjects

In many studies, large differences were noted between the responses of the different test subjects. In some instances, the question of the source of this variance was directly addressed. In surprisingly few cases did respondent sex or age emerge as a correlate of variance. The paucity of age-related findings may be due to the fact that many studies used university students, an age-homogeneous population, as the test group. Most of the tests did, however, include roughly equal cells of men and women.

A few studies probed more deeply into sources of variance. Nelson et al[38a] found that peppermint improved performance in a sustained reaction task only among those subjects who reported that they had become inattentive as the vigil progressed; it had no effect upon those who reported high levels of attentiveness even at the end of the task. Redd and Manne[66] found that the effectiveness of heliotropin in reducing anxiety during a magnetic resonance imaging (MRI) scan was related to patients' degree of anxiousness as they awaited the scan, as well as to their ability to detect the fragrance and to their rating of the fragrance as pleasant or relaxing. Ehrlichman and Bastone[47] found that the evaluation of ambiguous portraits and words was affected by pleasant and unpleasant odors only among those respondents who were highly "field-dependent," that is, those who tended to rely upon information as given rather than actively restructuring it and who tended to be guided in their responses by contextual cues rather than internal frames of reference.

These findings regarding the importance of psychological pre-disposition for the effectiveness of Aroma-Chology, isolated though they still are, appear plausible and important.

4.7—Opportunities and Limitations

I close with a few summarizing remarks regarding the opportunities and limitations of Aroma-Chology, as they appear to me on the basis of current evidence.

Based upon the experimental findings reviewed in this paper, manyfold novel uses of fragrance have been suggested in recent years. Examples include reducing patient stress in operating and medical treatment rooms, improving performance at the place of work, promoting well-being in meeting rooms and hotel lobbies and creating a pleasing atmosphere in retail establishments.

The idea to employ environmental fragrances to enhance specific emotional states and predispositions is by no means new. The use of scent in temples and at religious ceremonies, at feasts and celebrations, and for the promotion of love goes back as far as recorded history. What is new are the specific applications being suggested today; they reflect the needs and priorities of our times.

New, and again typical of our age, is also the scientific spirit of controlled experimentation and statistical analysis which Aroma-Chology brings to bear upon this field.

New to our contemporary society is also the awareness of the importance of the sense of smell which underlies all research into and applications of Aroma-Chology. Reflecting our strong visual-auditory bias, we have for many years confined our efforts to optimize mood and dispositions through environmental engineering to operations upon the visual and auditory elements of our surroundings. We have used soothing rather than exciting colors in doctors' and dentists' waiting and operating rooms and also, for somewhat different reasons, in hotel lobbies and rooms. We have carefully engineered the lighting conditions in offices and other working places to optimize performance and to minimize fatigue. We have excluded noise in places where concentration is required and have piped relaxing music into hotel lobbies, stores and airplanes. The idea to supplement such efforts by olfactory measures, although standard practice in ancient and in other contemporary cultures, opens new perspectives to our own society.

These perspectives include not only institutional uses of fragrance but also the individual, personalized use to enhance one's mood or alertness or to promote concentration.

As they suggest opportunities, the data reviewed here also point to limitations. In view of the great interindividual variance of response, the assumption that a given fragrance works equally for everybody is unwarranted. Until and unless indirect, cognition-mediated responses have been excluded we should, moreover, be wary of applying findings obtained in one country to other countries with different odor cultures.

We must also beware of generalization with respect to the stimulus. If, for example, a certain rose fragrance has been found to have a stress-relieving effect, we must not conclude that all other rose fragrances will have a similar effect.

We should also be aware of possible counterproductive effects of conditioning. If a fragrance that was found to be stress-relieving is repeatedly applied in a stressful situation, the possibility arises that this fragrance, by becoming associated with the situation, becomes itself stress-promoting. The experiment of Kirk-Smith et al[77] which suggests this possibility should be tested by replication by others.

Since nearly all of the reported studies involve one-time applications of odor stimuli, we know little about the extent to which the observed effects will prevail under conditions of long-time repeated exposure.

The manyfold findings regarding the effect of odors on moods and dispositions have generated not only optimistic and sometimes visionary thoughts about new uses of fragrance; they have also raised concerns. These can be subsumed under two headings: health concerns and concerns regarding manipulation.

Concerns about the health effects of exposing people to fragrances that are released into the atmosphere must, of course, be taken very seriously. Two considerations should, however, mitigate the gravity of such concerns. For one thing, the fragrances used in Aroma-Chology exploration and, presumably, the fragrances considered for actual use are made up exclusively of materials for which a very considerable record of safety has been established as a result of their use, over many years, in perfumes and in personal and household products of all kinds. For another, the accumulated evidence shows that the fragrances are most effective at very low concentrations.

While all claims of negative health effects must be looked into, they must not uncritically be held to be legitimate. The experiment of Knasko et al[75] on the presumed health effects of feigned odors shows that auto-suggestion is possible. This is another key experiment that should be tested by others.

Concerns about manipulation are based on the consideration that the individual concerned, since he or she has to breathe, cannot at will avoid exposure, coupled with the finding that odors can affect mood and behavior even at below-awareness levels. The concerns are raised primarily in two contexts: the use of fragrance to enhance worker efficiency in offices and other settings, and its use for stimulating purchasing behavior.

With respect to the efficiency-raising concern, one finds that ergonometric, visual (lighting) and auditory measures have long been accepted without question. Olfactory measures differ from these only in that they are novel.

With respect to purchasing behavior, there is little evidence to support concerns that shoppers can be seduced, through environmental odors, into buying things they do not want or need. The bulk of the work reviewed here makes it very unlikely that this could actually be achieved. In particular, the studies conducted by Knasko[63] and by Teerling et al[62] do not point to significant increases in purchasing as a result of environmental fragrances. The report by Hirsch[65] on the effects on an environmental odor on gambling sharply contrasts with this picture by claiming highly significant effects. Until and unless it is replicated, we must regard this report with scepticism.

5. Conclusions

Aroma-Chology is still in its infancy. It is marked by a multitude of experimental approaches. There are few methods available for distinguishing between direct and indirect (cognition-mediated) effects, a distinction essential for an understanding of the findings. Definition of the odor stimuli used is often so imprecise that replication of experiments is impossible. Many of the investigations are no more than pilot studies, using small test populations that are not necessarily typical of larger population groups. Some of the most intriguing findings come from a single study only, with as yet no attempt at confirmation or replication.

Nevertheless, we feel that the following tentative conclusions appear warranted today:

1. Odor stimuli can affect mood, anxiety and stress, arousal, performance in cognitive tasks such as memorizing and memory retrieval, sustained attention and problem solving, and perception of ambiguous stimuli. They can also affect simple behavior such as lingering time.
2. These effects can be elicited both by consciously and by subliminally perceived odors.
3. The degree to which an odor is liked or disliked by the subject (hedonics) materially affects its effects upon mood and cognitive performance.
4. Odor effects on mood are mediated by prior experience and expectations.
5. Because of 3 and 4 above, odor effects are probably influenced by social learning and are likely to be culture specific.
6. Odor effects on mood and performance are subject to large inter-individual variance. Individual predispositions such as field dependence play an important role. There is little evidence for sex- or age-related variance.
7. There is no fundamental difference between the effects of single essential oils, single aroma chemicals (natural or synthetic) and blends of natural and synthetic materials (fragrance compositions).
8. The effects of blends cannot be predicted from the effects of their components.
9. There is little evidence for significant positive effects of odor on complex human behavior such as purchasing.

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References

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1. *Living Well With Your Sense of Smell*, New York: Fragrance Research Fund (1992) p 21
2. R Tisserand, Essential oils as psychotherapeutic agents, in *Perfumery: The Biology and Psychology of Fragrance,* S Van Toller and GH Dodd, eds, London: Chapman Hall (1988) pp 167-182
3. G Carsh, Aromatherapy, a status review and commentary, *Soap Cosmet Chem Spec* **88**(8) 36-42 (1987)
4. M Indo, *Koryo*, No 168 p 43 (1990) (in Japanese, translated by Takasago International)
5. H Lawless, Effects of odors on mood and behaviour: aromatherapy and related effects, in *The Human Sense of Smell*, DG Laing, RL Doty and W Breipohl, eds, Berlin: Springer Verlag (1991) pp 362-386

6. TS Lorig, Human EEG and odor response, *Progress in Neurobiology* **33** 387-398 (1989)
7. TS Lorig, Cognitive and non-cognitive effects of odour exposure, in *Fragrance: The Psychology of Perfume,* S Van Toller and GH Dodds, eds. London: Elsevier (1992) pp 161-173
8. S Van Toller, Emotion and the brain, in *Perfumery: The Psychology and Biology of Fragrance,* S Van Toller and GH Dodd, eds, London: Chapman Hall (1988) pp 121-146
9. S Van Toller, J Behan, P Howells, M Kendal-Reed and A Richardson, An analysis of spontaneous human cortical EEG activity to odours, *Chem Senses* **18** 1-16 (1993)
10. G Kobal and T Hummel, Cerebral chemosensory evoked potentials elicited by chemical stimulation of the human olfactory and respiratory nasal mucosa, *Electroencephalography and Clinical Neurophysiology* **71** 241-250 (1988)
11. G Kobal and T Hummel, Olfactory evoked potential activity and hedonics, in *Fragrance: The Psychology and Biology of Perfume,* S Van Toller and GH Dodd, eds, London: Elsevier (1992) pp 175-194
11a. Ibid, pp 193-194
12. H Ehrlichman, Hemispheric asymmetry and positive-negative affect, in *Duality and Unity of the Brain: Unified Functioning and Specialization of the Hemispheres,* D Ottoson, ed, London: Macmillan (1986) pp 194-206
13. Y Saito, T Yamamoto and S Kanamura, Scented environment and ERP basis waves (2), *Chem Senses* **16** 202 (1991)
14. S Torii, H Fukuda, H Kanemoto, R Miyanchi, Y Hamauzu and M Kawasaki, Contingent negative variation (CNV) and the psychological effects of odour, in *Perfumery: The Psychology and Biology of Fragrance,* S Van Toller and G Dodd, eds, London: Chapman Hall (1988) pp 107-120
15. S Kanamura, S Kiyota, Y Takashima, T Kariisana, M Indo, GV Loveren, H Fukuda and S Torii, Effect of odors on CNV IV, *Chem Senses* **14** 303-304 (1989)
16. TS Lorig and M Roberts, Odor and cognitive alteration of the contingent negative variation, *Chem Senses* **15** 537-545 (1990)
17. J Tecce, J Savigerano-Berman and D Meinbresse, Contingent negative variation and the distraction-arousal hypothesis, *Electroencephaly Clin Neurophysiol* **41** 277-286 (1976)
18. H Sugano, Psychophysiological studies of fragrances, in *Fragrance: The Psychology and Biology of Perfume,* S Van Toller and GH Dodd, eds, London: Elsevier, (1992) pp 221-228
19. H Sugano, Effects of odors on mental function, *Chem Senses* **14** 303 (1989)
19a. Y Okazaki, Perfumes and application of contingent negative variation, *Fragrance Journal* **20**(10) 80 (1992) (in Japanese)
20. TS Lorig and GE Schwartz, Brain and odor I: Alteration of human EEG by odor administration, *Psychobiology* **16** 281-289 (1988)
21. TS Lorig and GE Schwartz, EEG during relaxation and food imagery. *Imagination, Cognition and Personality* **8** 201-208 (1989)
22. M Nakagawa, H Nagai and T Inui, Evaluation of drowsiness by EEGs - Odors controlling drowsiness, *Fragrance Journal* **20**(10) 68-72 (1992) (in Japanese)
23. T Yoshida, S Sorito, T Iida, M Yamamura and S Kanamura, Effect of odors on frequency fluctuation of brain waves, *Chem Senses* **14** 311 (1989)
24 T Yoshida, The measurement of frequency fluctuations of brain waves, *Fragrance Journal* **20**(10) 23-29 (1992) (in Japanese)
25. T Ishitoya, Effects of a fragrance on stress and fluctuation of EEG, *Fragrance Journal* **19**(92) 50-54 (1991) (in Japanese)
26. European Patent 0183 436 B 2 (published Mar 7, 1991)
27. Konishi et al, *J of Japanese Cosm Soc* **3** 140 (1989)
28. A Kikuchi, M Tanida, S Uenoyama, T Abe and H Yamaguchi, Effect of odours on cardiac response patterns in a reaction time task, *Chem Senses* **16** 183 (1991)
29. M Oguri, T Iwaki, S Ogata, Y Okazaki and S Torii, Coincidental variations between heart rate and contingency negative variation during odor condition, *Chem Senses* **16** 197-198 (1992)
30. W Steiner, Die Wirkung von Gerüchen auf das Erleben und Verhalten des Menschen, in P Jellinek, *Die psychologischen Grundlagen der Parfümerie,* 4th ed, Heidelberg: Hüthig (1994) pp 209-211
31. R Parasuraman, JS Warm and WN Dember, Effects of olfactory stimulation on skin conductance and event-related brain potentials during visual induced attention, *Progress Report No 6 to Fragrance Research Fund* (1992)
32. S Kanamura, M Kawasaki, M Indo, H Sukuda and S Torii, Effects of odours on the contingent negative variation and the skin potential level, *Chem Senses* **13** 326 (1988)
33. Y Niimi, *Proceedings of the 4th Takasago Symposium* (1986) p 45
34. W Steiner, E Hanisch and D Schwarz, Geruchserlebnis und Pupillenerweiterung - eine experimentelle Untersuchung, *Parf u Kosm* **58** 189-196 (1977)
35. Y Miyazaki, S Takenchi, M Yatagai and S Kobayashi, The effect of essential oil on mood in humans, *Chem Senses* **16** 1984 (1991)
36. H Nagai, M Nakamura, W Fujii, T Inui and Y Asakura, Effects of odors on humans II, Reducing effects of mental stress and fatigue, *Chem Senses* **16** 198 (1992)
37. A Ehrlichman, The startle-probe reflex as an indicator of affective response to odor, *Final Report to the Olfactory Research Fund* (1993)
38. JS Warm, WN Dember and R Parasuraman, Effects of olfactory stimulation on performance and stress in a visual sustained attention task, *J Soc Cosm Chem* **42** 199-210 (1992)
38a. WT Nelson, PL Grubb, JS Warm and WN Dember, The effects of fragrance administration and attentiveness on vigilance performance, Presentation at the meeting of the Southern Society for Philosophy and Psychology, Memphis (1992)
39. JS Warm, R Parasuraman and WN Dember, Effects of periodic olfactory stimulation on visual sustained attention in young and older adults, *Progress Report No. 4 to the Fragrance Research Fund* (1990)
40. E Karamat, J Ilmberger, C Buchbauer, K Rößlhuber and C Rupp, Excitatory and sedative effects of essential oils on the human reaction time performance, *Chem Senses* **17** 847 (1992)
41. Y Miyake, M Nakagawa and Y Asakura, Effects of odours on humans (I), Effects of sleep latency, *Chem Senses* **16** 183 (1991)
42. JB Frank and EJ Ludvigh, The retro-active effect of pleasant and unpleasant odors on learning, *Am J of Psychology* **43** 102-108 (1931)
43. W Steiner, The effect of the fragrances on human experience and behaviour, *drom Report "The Nose, Part 3"* (1986) pp 6-21
44. HW Ludvigson and TR Rottmann, Effects of ambient odours of lavender and cloves on cognition, memory, affect and mood, *Chem Senses* **14** 525-536 (1989)
45. KH Berg, The effect of smell on cognitive processes, *Dragoco Report* **39** 128-129 (1987)
46. H Ehrlichman and JN Halpern, Affect and memory: Effects of pleasant and unpleasant odors on retrieval of happy and unhappy memories, *Journal of Personality and Social Psychology* **55** 769-779 (1988)
47. H Ehrlichman and C Bastone, The Use of odor in the study of emotion, in *Fragrance: The Psychology and Biology of Perfume,* S Van Toller and GH Dodd, eds, London: Elsevier (1992) pp 143-159
48. SC Knasko, Ambient odor's effect on creativity, mood and perceived health, *Chem Senses* **17** 27-35 (1992)
49. H Sugano and H Sato, Psychophysiological studies of fragrance, *Chem Senses* **16** 183-184 (1991)
50. W Steiner, Der Einfluß erogener Duftstoffe auf die visuelle Wahrnehmung erotischer Reize, in P Jellinek, *Die psychologischen Grundlagen der Parfümerie,* Heidelberg: Hüthig (1994) pp 200-201
51. DR Goodenough, Field dependence, in *Dimensions of Personality,* H London and SE Exner, eds, New York: Wiley (1978) pp 165-216
52. A Cann and DA Ross, Olfactory stimuli as context cues in human memory, *Amer J of Psychol* **102** 91-102 (1989)

53. RA Baron, Environmentally-induced positive effect: Its impact on self-efficacy, task performance, negotiation and conflict, *J Applied Social Psychol* **20** 369-394 (1990)
54. J Rotton, Affective and cognitive consequences of malodorous pollution, *Basic and Applied Social Psychol* **38** 213-228 (1983)
55. SC Knasko, Performance, mood and health during exposure to intermittent odors, *Archives of Environmental Health* **48** 305-308 (1993)
56. P Badia, M Boecker and W Lammers, Some effects of different olfactory stimuli on sleep, *Sleep Research* **19** 195 (1990)
57. M Boecker et al, Olfactory stimulation in sleep: a follow-up study, *Sleep Research* **20** 155 (1991)
58. M Boecker and P Badia, The effects of the odor androstenone on sleep, *Sleep Research* **21** 142 (1992)
59. T Lorig, Human EEG and odor response, *Progress in Neurobiology* **285** 1-11 (1989)
60. P Badia, Olfactory sensitivity in sleep and the effects of fragrances on the quality of sleep, *Final Report to the Fragrance Research Fund* (1992)
61. M Willer, S Goodewill and H Hatt, Olfaction sensitivity of humans in sleep, *Chem Senses* **17** 892-893 (1992)
62. A Teerling, RR Nixdorf and EP Köster, The effect of ambient odours on shopping behaviour, *Chem Senses* **17** 886 (1992)
63. SC Knasko, Ambient odor and shopping behaviour, *Chem Senses* **14** 718 (1989)
64. SC Knasko, Lingering time in a museum in the presence of congruent and incongruent odours, *Chem Senses* **18** 581 (1993)
65. AR Hirsch, Effect of ambient odour on slot-machine usage in a Las Vegas casino, *Chem Senses* **18** 578 (1993)
66. WH Redd and SL Manne, Fragrance administration to reduce patient anxiety during magnetic resonance imaging in cancer diagnosic work-up, *Report to Fragrance Research Fund* (1991)
67. SL Manne and WH Redd, Fragrance administration to reduce patient anxiety during magnetic resonance imaging in cancer diagnosic work-up, *Final Report to Olfactory Research Fund* (1993)
68. E Hanisch, The calming effect of fragrances and associated remembrances, in *drom Report "The Nose, Part 2"* (1982) pp 18-19
69. C Warren and S Warrenburg, Mood benefits of fragrance, *Perf & Flav* **18**(2) 9-16 (1993)
70. MD Kirk-Smith and DA Booth, Effects of natural and synthetic odorants on mood and perception of other people, *Chem Senses* **17** 849-850 (1992)
71. RA Baron, Olfaction and human social behaviour: Effects of pleasant scents on physical aggression, *J Basic and Applied Social Psychol* **1** 163-172 (1980)
72. SC Knasko, Viewing time and liking of slides in the presence of congruent and incongruent odors, *Chem Senses* **17** 652 (1992)
73. S Schiffman, The Effect of fragrance on the mood of woman at mid-life, *The Aroma-Chology Review* **2**(1) 1-5 (1993)
74. S Schiffman, Effect of pleasant odor: on mood of males at mid-life, *Final Report to the Olfactory Research Fund* (1993)
75. SC Knasko, AN Gilbert and J Sabini, Emotional state, physical well-being and performance in the presence of feigned ambient odor, *J Applied Social Psychol* **20** 1345-1357 (1990)
76. MD Kirk-Smith and DA Booth, Chemoreception and human behaviour: Experimental analysis of the social effects of fragrances, *Chem Senses* **12** 159-166 (1987)
77. MD Kirk-Smith, S Van Toller and GH Dodd, Unconscious odor conditioning in human subjects, *Biol Psychol* **17** 221-231 (1983)
78. S Penchey, The Compleat Herbal of Physical Plants, London (1694); quoted by R Tisserand, Essential oils as psychotherapeutic agents, in *Perfumery: The Biology and Psychology of Fragrance*, S Van Toller and GH Dodd, eds, London: Chapman Hall (1988) p 168
79. R Tisserand, Essential oils as psychotherapeutic agents, in *Perfumery: The Biology and Psychology of Fragrance*, S Van Toller and GH Dodd, eds, London: Chapman Hall (1988) pp 174,176