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# Basic Emotions Evoked by Eugenol Odor Differ According to the Dental Experience. A Neurovegetative Analysis

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## Abstract

Subjective individual experiences seem to indicate that odors may form strong connections with memories, especially those charged with emotional significance. In the dental field, this could be the case with the odorant eugenol, responsible for the typical clinging odor impregnating the dental office. The odor of eugenol could evoke memories of unpleasant dental experiences and, therefore, negative feelings such as anxiety and fear, since eugenates (cements containing eugenol) are used in potentially painful restorative dentistry. This hypothesis was tested by evaluating the emotional impact of the odor of eugenol through autonomic nervous system (ANS) analysis. The simultaneous variations of six ANS parameters (two electrodermal, two thermovascular and two cardiorespiratory), induced by the inhalation of this odorant, were recorded on volunteer subjects. Vanillin (a pleasant odorant) and propionic acid (an unpleasant one) served as controls. After the experiment, subjects were asked to rate the pleasantness versus unpleasantness of each odorant on an 11-point hedonic scale. The patterns of autonomic responses, obtained for each odorant and each subject, were transcribed into one of the six basic emotions defined by Ekman *et al.* (happiness, surprise, sadness, fear, anger and disgust). Results were compared between two groups of subjects divided according to their dental experience (fearful and non-fearful dental care subjects) and showed significant differences only for eugenol. This odorant was rated as pleasant by non-fearful dental subjects but unpleasant by fearful dental subjects. The evoked autonomic responses were mainly associated with positive basic emotions (happiness and surprise) in non-fearful dental subjects and with negative basic emotions (fear, anger, disgust) in fearful dental subjects. These results suggest that eugenol can be responsible for different emotional states depending on the subjects' dental experience, which seems to confirm the potential role of odors as elicitors of emotional memories. This study also supports the possible influence of the ambient odor impregnating the dental office, strengthening a negative conditioning toward dental care in some anxious patients.

## Introduction

Previous studies by Berggren and co-workers (Berggren and Meynert, 1984; Berggren *et al.*, 1997) have shown that the acquisition of dental anxiety in many cases may be due to either previous traumatic experiences or to social-learning modeling of fearful behaviors. Among the traumatic factors which could explain fear of dentistry, Kleinknecht *et al.* (1973) showed that the greatest sources of fear in dental treatment are the anesthetic needle and the drill. Another conditioning dental fearful stimulus, which has received little attention until now, could be the characteristic clinging odor of the dental office, due to eugenol. Yet, the item 'smell of dental office' is included in the Dental Fear Survey, a widely used test to investigate dental fear and anxiety (Kleinknecht *et al.*, 1973). In a recent study by Hakeberg and Berggren (1997), this item was rated with high scores by a majority of patients with dental phobia. As underlined by Lorig (1989), odor and the sense of smell are very important in the direction of human behavior and several studies have revealed effects of odors on cognition, emotion, mood and memory (Van Toller, 1988; Ludvigson and Rottman, 1989; Ehrlichman and Bastone, 1992). Concerning the latter point, odors are believed to form powerful connections with memories, especially those from the distant past charged with emotional significance (Richardson and Zucco, 1989; Ehrlichman and Bastone, 1992). One explanation could be that the olfactory system has major anatomical connections with brain structures involved in emotion and memory, such as the hypothalamus and limbic system (Aggelton and Mishkin, 1986).

It can thus be suggested that eugenol odor could evoke memories of unpleasant dental experiences and contribute to dental anxiety and fear. This is supported by the results of Kirk-Smith *et al.* (1983), who demonstrated that if an unfamiliar odor is associated with a stressful situation, this odor may, at a later time, elicit concomitant mood and attitudinal changes. In the case of eugenol, its association with unpleasant dental care experiences could be explained by the fact that eugenates (cements containing eugenol) are often used in potentially painful restorative dentistry on vital teeth.

In a recent study (Robin *et al.*, 1998), we have evaluated, through simultaneous recording of six autonomic nervous system (ANS) parameters, the emotional impact of dental odorants and especially eugenol, responsible for the typical odor of the dental office. The variations of the ANS parameters induced by the inhalation of this odorant were compared between two groups of subjects divided according to their dental experience (fearful and non-fearful dental care subjects). The results showed that eugenol odor induced significantly different patterns of ANS responses between the two groups with stronger variations in the fearful dental subjects. It was suggested that these results reflect the particular significance of this odor to fearful subjects, evoking unpleasant feelings such as anxiety and fear related to their dental experience. However, one limitation of this study was that it provided only quantitative data from the variations of the ANS parameters. Moreover, the stronger differences between the two groups of subjects were mainly observed through one ANS channel (the electrodermal channel), so that information obtained through the other ANS channels (thermovascular and cardiorespiratory) could not be taken into account for the data analysis. The same conclusion was made by Alaoui-Ismaïli *et al.* (1997a), who studied the relation between the hedonic valence of five odorants and the autonomic parameter variations induced by the inhalation of these odorants. A significant correlation between autonomic responses and the subject's hedonic estimation for all the odorants was obtained only through the skin resistance and heart rate parameters. It was concluded that it would be more interesting to consider the global pattern of ANS responses rather than each parameter separately. Such an approach can be realize if each ANS pattern is transcribed into a basic emotion, allowing a qualitative analysis of the response in addition to the quantitative one (Vernet-Maury *et al.*, 1995a).

Defined by Ekman *et al.* (1983), basic emotions (happiness, surprise, sadness, fear, anger and disgust) can be considered as psychophysiological entities that are behaviorally observed and cross-culturally distinguished. They are characterized by a rapid onset, a short duration and a spontaneous occurrence explaining that ANS, a highly and rapidly activated system, is capable of differentiating among them (Schwartz *et al.*, 1981; Ekman *et al.*, 1983; Uchiyama, 1992; Collet *et al.*, 1997). Phillips *et al.* (1997) have even demonstrated, using functional magnetic resonance imaging, the existence of distinct neural substrates for perception of disgust, involving primarily the anterior insula, and of fear, involving the amygdala.

In a recent study (Alaoui-Ismaïli *et al.*, 1997b), basic emotions could be associated with different odorants from the global autonomic response pattern induced by the inhalation of each odorant. This approach allowed us to demonstrate that pleasantly connoted odorants were mainly associated with 'positive' emotions (happiness and surprise), whereas unpleasantly connoted odorants were associated with 'negative' emotions, mainly disgust and anger.

The purpose of this study was to transcribe the global ANS pattern induced by the inhalation of the odorant eugenol into a basic emotion and to compare the distribution of the basic emotions between fearful and non-fearful dental subjects. It was expected that the basic emotions associated with eugenol odor could differ between these two groups of subjects in relation to their dental experience. A pleasant odorant (vanillin) and an unpleasant one (propionic acid) were used as controls. In addition to ANS (unconscious) basic emotions, the distribution of verbal (self-estimated, conscious) emotions was also reported since differences from these two methods of evaluation were previously observed concerning, especially, unpleasant odors (Alaoui-Ismaïli *et al.*, 1997b).

## Materials and methods

### Subjects and odorants

Forty-four healthy, non-smoker volunteer students (20 males and 24 females) served as subjects. Their mean age was 25 years, ranging from 20 to 28 years. All subjects participated as part of practical works of applied physiology (University Lyon I) after providing informed consent to the protocol.

The three diluted odorants in ethanol 95 (eugenol 0.15%, vanillin 1% and propionic acid 0.015%) were delivered in a randomized order and were always preceded by a pleasant odorant (lavender 1%) in order to suppress the surprise effect induced by the first stimulus. The concentration of each odorant was adjusted to be clearly recognizable without stimulating the trigeminal nerve endings (no pungent sensation in the nose).

### Procedure

Subjects were individually involved in an olfactory test session lasting ~40 min. Odorants were delivered from an olfactometer where compressed air (5.1 l/min), purified by passing through different kinds of filters, fed the glass flasks containing the odorants. Two clips placed on the rubber tube at the entrance and the exit of each flask permitted the delivery of odors to the subjects through a two-outflow glass tube fixed under the nostrils (Alaoui-Ismaïli *et al.*, 1997b). An output from the polygraph enabled the experimenter to synchronize odor presentation with the inhaling part of the breathing cycle.

Prior to experimental sessions, subjects were informed verbally about the procedure. They were made aware that an odorant was to be delivered but they did not know when. During the test, subjects were alone in the experiment room (temperature = 22°C), isolated from the experimental device. Odorants were delivered for 5 s with variable time intervals of ~2 min, when ANS parameters had recovered their prestimulus basal level after each response.

After the experimental session, the odorants were again delivered to the subjects, who were asked to identify (if possible) each odorant, to situate it on an 11-point hedonic scale (from 0 = highly pleasant to 10 = highly unpleasant) and to associate it to one of the six basic emotions listed on a paper in front of them (verbal or conscious basic emotions).

From the 44 subjects, 19 (6 males and 13 females) identified the odorant eugenol as the typical odor of the dental office. Each of these subjects was then asked to specify his or her attitude toward dental care (apprehensive or not) and the feelings associated with this evocation (unpleasant or not). This allowed us to divide them into two groups: non-fearful dental subjects ($n$ = 7: 2 males and 5 females), for whom no unpleasant connotation was associated with the dental office or dental care, and fearful dental subjects ($n$ = 12: 4 males and 8 females), who reported an aversive attitude toward dental care. Subjects who did not explicitly associate eugenol with the dentist were not included in this study since their responses could not be interpreted in terms of dental fear. However, an analysis of the ANS responses of the 44 subjects, induced by the inhalation of different odors (including eugenol), has previously been performed and discussed according to the hedonic valence of the odorants (Alaoui-Ismaïli *et al.*, 1997b).

### Autonomic nervous system parameters

Throughout the olfactory test, six ANS parameters were simultaneously and continuously recorded with no interference: skin potential (SP) and skin resistance (SR) (electrodermal parameters), skin blood flow (SBF) and skin temperature (ST) (thermovascular parameters), and instantaneous respiratory frequency (IRF) and instantaneous heart rate (IHR) (cardiorespiratory parameters).

#### *Skin resistance*

SR was recorded using 25 mm² Ag/AgCl round electrodes (Clark Electromedical Instruments E 243, Reading, UK), placed on the second phalanx of the index and the third digit of the non-dominant hand, held by adhesive tape. Electrode positioning was in compliance with traditional recommendations (Fowles *et al.*, 1981). Resistance was measured by a 15 µA DC current. As response amplitude depends on the prestimulation value (Wilder, 1962), a more reliable index was defined: the time during which the subject responds to the stimulus without referring to the initial value (or tonic level). This index, called OPD (for ohmic perturbation duration), was shown to reflect the emotional load of the stimulus (Vernet-Maury *et al.*, 1995b).

#### *Skin potential*

SP was recorded using Beckman 78 mm² electrodes, fixed by double-sided adhesive tape. Electrode positioning and electrode cream were in compliance with traditional recommendations (Fowles *et al.*, 1981). The active electrode was placed on the hypothenar eminence of the subject's non-dominant hand (after alcohol–ether cleaning of the skin). The reference electrode was placed 10 cm higher on the wrist (on the equidistant line of the median plane and the outer extremity of the forearm). Electrodermal potential variations were analyzed with the SYDER code (Dittmar *et al.*, 1995), which permits classification of elementary responses according to their form (A, B, C), sign (+ or –) and duration.

#### *Skin blood flow*

SBF was assessed using the original Hematron patented sensor (Dittmar, 1989). The non-invasive sensor was placed on the skin with adhesive tape (thenar eminence of the non-dominant hand). The transducer consisted of a disk 25 mm in diameter and 4 mm thick. The measuring surface in contact with the skin was made up of two parts: the reference area at the periphery of the disk, and the measurement area at the center of the disk. The temperature difference between these two areas was measured using 16 thermocouple junctions. A very low thermal inertia flat heater was located in the central part of the disk. A proportional, integrative and derivative device controlled the heating power in order to maintain a constant temperature difference of 2°C between the central area and the periphery. The size and shape of the heater were designed in such a manner that a thermal field was induced in the capillary network. The power necessary to maintain the temperature difference constant depends on SBF: heat is transferred through the skin and washed out by the blood flow. At all times, electric power is proportional to the heat evacuated by the tissue blood flow (Dittmar, 1989).

Blood flow in capillaries is submitted to microchanges reflecting variations of emotional load. SBF variations were measured by the duration of the oscillation break period induced by the stimulus. At rest, SBF recording shows spontaneous and regular oscillations which disappear when the subject is under the stimulation. The duration of the pertubation of these oscillations is expressed in seconds through the NOD index (for non-oscillatory duration) (Vernet-Maury *et al.*, 1991).

#### *Skin temperature*

ST was measured by a slow inertia thermistor (10 K3 MCD2 Betatherm). A 4 mm² sensor was placed in the middle of the palm of the non-dominant hand with non-caustic glue. A variation of about one-thousandth of a degree can be detected under such conditions. With regard to the different subjects' thermal balance, the amplitude variation (positive or negative) was measured by the difference between the tonic temperature level and the phasic variation, using the disrupted slope of the graph. For the same reason, duration was measured from the onset of the phasic response to this disrupted slope of the graph.

#### *Instantaneous respiratory frequency*

IRF was recorded from an oblong thermistor (length 10 mm, diameter 3 mm), placed at the entrance of the left nostril with hypoallergenic adhesive tape. The processed signal gives the IRF on the basis of the difference in temperature between inhaled and exhaled air.

#### *Instantaneous heart rate*

IHR was recorded from three silver electrodes in a precordial position. The D2 derivation signal (interval between two consecutive R waves) was processed and delivered in the form of instantaneous heart frequency. The smallest appreciable variation was 0.5 beats/min and the calibrated scale ranged from 0 to 200 beats/min.

### Recording system and signal analysis

The six measured signals were recorded by a 80286 microcomputer (Toshiba T3200). Signal sampling was carried out by a 16-bit data acquisiton card (ADAC 5508HR) at a frequency of 8 Hz. Signals were recorded in parallel by a six-channel potentiometric DC recorder (YTSE 460 type BBC) to allow rapid visual inspection of the recordings and quality control of experimentation.

A special software package was designed and developed for rapid analysis and processing of the recorded data. The interactive software permits calculation of all indices (including waveform pattern recognition of SP responses). The software features have other uses, such as amplification and attenuation of signals and zooming. A digital signal processing library of functions was designed and added to the software in order to allow processing of all types of artefacts and to filter random noise whenever present in the recorded signals (Rada *et al.*, 1995).

### Data analysis and extracted parameters

Data analysis was performed through the five following extracted parameters: (i) the sign (+ or –) and the form of the SP response (A, B or C), according to the SYDER code (Dittmar *et al.*, 1995), which reflects the duration of the response (the A form corresponds to the shortest responses and the C form to the longest responses); (ii) the duration of the SR response, expressed in seconds, with the OPD index (Vernet-Maury *et al.*, 1995b); (iii) the duration of the SBF response, expressed in seconds, corresponding to the non-oscillatory period induced by the stimulus (NOD index; Vernet-Maury *et al.*, 1991); (iv) the amplitude and the sign (+ or –) of the ST response; and (v) the variation (increase or decrease) of the IHR response expressed in beats/min. The variations of the respiratory frequency were not taken into account for the data analysis since the inhalation of the odorants could interfere with the respiratory response. However, this parameter was useful for controlling the time when the odor was detected by the subject.

### ANS basic emotions

ANS responses were analyzed subject by subject and odorant by odorant. The pattern of ANS responses, obtained for each odorant, was transcribed into one of the six basic emotions (happiness, surprise, sadness, fear, anger and disgust) using a decision tree built from different autonomic analysis, especially those of Ekman *et al.* (1983) and Collet *et al.* (1997) (Figure 1). The responses obtained through each ANS parameter were calculated for each odorant, as previously explained. Their magnitude was then evaluated as strong (+++), medium (++) or weak (+), from a comparison between all responses of the subject and reported on the decision tree, allowing the association of each ANS pattern with one of the basic emotions (ANS basic emotion). This procedure is illustrated by an example in the 'Results' section.

### Statistical analysis

The following data were statistically compared, for each odorant, between the two groups of subjects (fearful and non-fearful dental subjects): the hedonic scores by a one-way ANOVA and the distribution of verbal and ANS basic emotions with the non-parametric Fisher test. All differences were considered significant at a level of $P < 0.05$.

## Results

### Hedonic scores

Comparison of hedonic scores (mean ± SEM) obtained for the three odorants between the two groups of subjects showed that vanillin was rated as pleasant, with no significant difference between the non-fearful (1.9 ± 1.1) and fearful dental subjects (1.9 ± 0.9), and propionic acid as very unpleasant, also with no significant difference between the non-fearful (8.3 ± 0.5) and fearful dental subjects (8.9 ± 0.4). Only eugenol was rated with a significant difference between the two groups: pleasantly by the non-fearful dental subjects (3.4 ± 0.7) and unpleasantly by the fearful dental subjects (7.8 ± 0.6) ($F = 21.94$, $P < 0.001$).

### Autonomic responses and basic emotions

An example of a simultaneous recording of the six ANS parameters in response to eugenol is presented in Figure 2. In this case, it can be observed that the odor of eugenol induced strong electrodermal (SR: OPD index = 40s ; SP: C+ form) and SBF (NOD index = 30 s) responses, a decrease of the ST and no significant perturbation of the

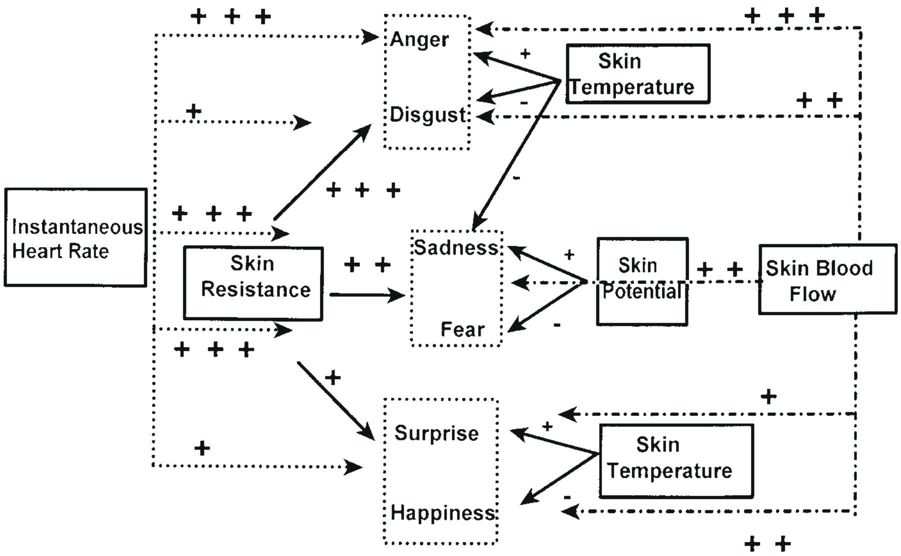


**Figure 1** Decision tree used to transcribe the ANS pattern, obtained for each odorant, into one of the six basic emotions (happiness, surprise, sadness, fear, anger and disgust). For SR, SBF and IHR, the response magnitude is indicated by + (weak), ++ (medium) or +++ (strong). For ST and SP, the sign of the response (+ or –) is taken into account.

IHR. According to the decision tree (Figure 1), the magnitude of these responses allow the association of this ANS pattern with 'disgust' (SR +++, IHR +, ST – and SBF ++).

The distribution of the verbal and ANS basic emotions associated with each odorant is presented in Figure 3. The number of basic emotions evoked by each of the three odorants is always greater from the autonomic (unconscious) estimation than from the verbal (conscious) estimation (vanillin: 3 verbal versus 6 ANS emotions; eugenol: 6 verbal versus 7 ANS emotions; and propionic acid: 4 verbal versus 6 ANS emotions). The repartition of the verbal as well as the ANS basic emotions is not significantly different between the two groups of subjects for the two non-dental odorants (vanillin: $P = 0.64$ and 0.36 for the verbal and ANS basic emotions respectively; propionic acid: $P = 0.64$ and 0.63 for the verbal and ANS basic emotions respectively). The pleasant odorant vanillin was mainly associated with happiness whereas the unpleasant odorant propionic acid was mainly associated with negative basic emotions, especially anger and disgust. By contrast, the odorant eugenol induced two significantly different patterns of verbal ($P = 0.036$) as well as ANS ($P = 0.006$) basic emotions between the two groups of subjects, with a greater proportion of positive basic emotions (happiness and surprise) in the non-dental fearful subjects and a greater proportion of negative basic emotions (fear, anger, disgust) in the dental fearful subjects. More particularly, it must be noted that the basic emotion fear was evoked at the conscious (verbal) level, as well as the unconscious (ANS) level, only in the dental fearful subjects.

## Discussion

The belief that odors may form powerful connections to memories, especially those charged with emotional significance, has been discussed by several authors (Van Toller, 1988; Lawless, 1991; Ehrlichman and Bastone, 1992). But, despite the popularity of this claim, Ehrlichman and Bastone (1992) concluded in their review that there is insufficient evidence at present to conclude that odor has a special ability to evoke emotional memories. One explanation could be that this phenomenon has received little scientific attention until now, with only a few studies in which autobiographical odor-evoked memories were explored (Herz and Cupchik, 1992). However, Herz and Cupchik (1992, 1995) have demonstrated that odor-evoked memories tend to be highly emotional, vivid and specific, and that odors evoked more emotional memories than did verbal odor labels. The primary olfactory projections onto the amygdala–hippocampal complex of the limbic system, which is known to be involved in emotion and memory processes, provide a neuroanatomical basis to this hypothesis.

In the dental field, a specific odorant, eugenol, could be potentially charged with a high emotional significance. The clinging odor of eugenol, which often impregnates the dental office, could evoke memories of unpleasant dental experiences, since eugenates (cements containing eugenol) are used in restorative dentistry on vital teeth. The operative procedures can be carried out on anesthetized or non-anesthetized teeth. However, the use of the drill, in addition to the sight of the anesthetic needle in the first case and the fear of pain in the second, represent the greatest sources of fear and anxiety in dental treatments (Kleinknecht *et al.*, 1973).

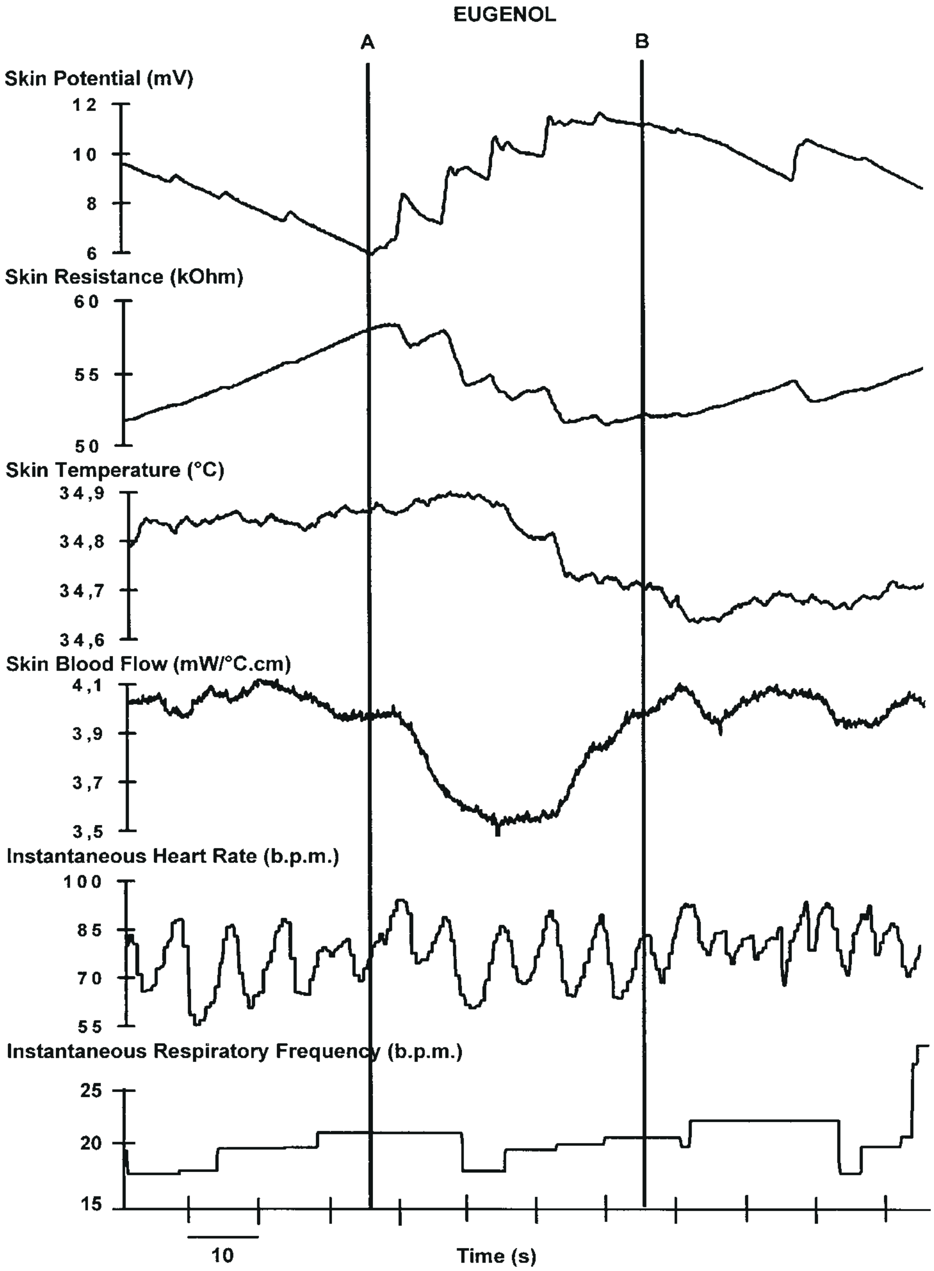


**Figure 2** Example of a recording of the simultaneous variations of the six ANS parameters in response to eugenol odor (A = beginning of the response, B = end of the response). The autonomic responses are characterized by strong electrodermal (SP and SR) and SBF variations, a decrease in ST and a weak IHR variation. According to the decision tree, this ANS pattern corresponds to the basic emotion 'disgust' (SR +++, IHR +, ST –, SBF ++).

This hypothesis was examined in a previous study by evaluating the quantitative variations of five autonomic parameters induced by the inhalation of the odor of eugenol (Robin *et al.*, 1998). These variations were compared between fearful and non-fearful dental subjects and showed that eugenol odor induced two significantly different patterns of ANS responses, mainly observed through the electrodermal channel. However, one limitation of this study was that it provided only quantitative data without taking into account the global pattern of the ANS responses, which has been shown to be more informative when it is transcribed into a basic emotion (Vernet-Maury *et al.*, 1995a; Alaoui-Ismaïli *et al.*, 1997b).

In this study, the patterns of the ANS responses induced by the inhalation of three odorants (eugenol, vanillin and propionic acid) were transcribed into one of the basic emotions and their distribution compared between fearful and non-fearful dental subjects. In both groups, basic emotions (ANS as well as verbal emotions) evoked by the pleasant odorant vanillin (mainly happiness) and by the

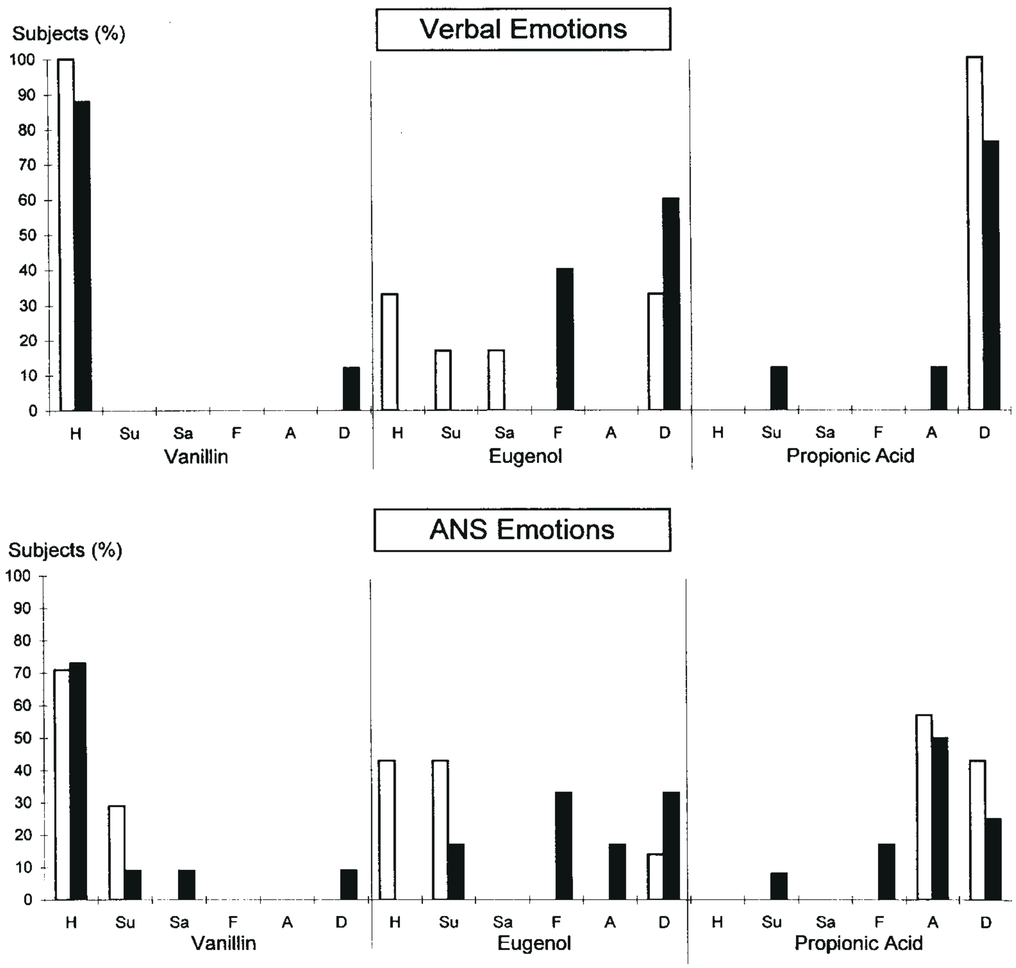


**Figure 3** Distribution (expressed in percentage of subjects) of the verbal and ANS basic emotions associated to vanillin, eugenol and propionic acid odors in the non-fearful (□) and fearful (■) dental care subjects. The comparison of these distributions between the two groups of subjects shows significant differences only for eugenol (verbal emotions: $P = 0.036$; ANS emotions: $P = 0.006$) (H = happiness, Su = surprise, Sa = sadness, F = fear, A = anger, D = disgust).

unpleasant one propionic acid (mainly disgust and anger) probably reflect the hedonic valence of these two odors. It has been shown that the magnitude of the physiological responses induced by odorants partially depend on their hedonic tone, pleasant odors inducing lower responses than unpleasant ones (Kobal *et al.*, 1991; Miltner *et al.*, 1994; Brauchli *et al.*, 1995, Vernet-Maury *et al.*, 1995a). By contrast, the distribution of the basic emotions evoked by the inhalation of the odor of eugenol differs according to the dental experience. For the non-fearful dental subjects, this odor was mainly associated with positive basic emotions (happiness and surprise) and, for the fearful dental subjects, this odorant evoked negative emotions (fear, anger and disgust).

Two main differences emerge from the comparison between the verbal (self-reported or conscious) evaluation of the basic emotions and the ANS (unconscious) one. The first is the greatest number of basic emotions found from the ANS evaluation, indicating that such estimation is probably more informative, reflecting more various emotional states. The second concerns the basic emotion anger, which is rarely expressed through the verbal channel whereas the ANS evaluation revealed a higher occurrence of this emotion. This phenomenon, previously observed in a greater number of subjects (Alaoui-Ismaïli *et al.*, 1997b), was also reported by other authors, in particular the confusion between anger and disgust (Bullock and Russel, 1986). For Vrana (1993), both the disgust and anger situations are predicted to produce self-reported judgements of 'disgusting' because one common-language meaning of disgust is disapproval of another's actions or principles, which is semantically similar to being cheated, a common anger theme.

Our results indicate that, at the conscious level (verbal estimation), the emotional state induced by an unpleasant odor (propionic acid) or by an odor evoking negative and aversive feelings (eugenol) is more easily expressed in terms of disgust. At the unconscious level (ANS estimation), this emotional state can always be traduced in terms of disgust, but also in terms of anger. Even though this phenomenon still remains poorly explained, one explanation of the non-verbalization of anger in an experimental context could be the result of a social inhibition.

If the high percentage of disgust, obtained in response to the propionic acid odor and, to a lesser degree, to the eugenol odor, may traduce an avoidance behavior toward an unpleasant odor, it cannot be the case for the basic emotion fear, which is rarely evoked by the propionic acid odorant yet judged as very unpleasant. Fear is characterized by a strong tachycardia, a decrease in ST, a moderate variation of the SR and SBF parameters and, especially, negative SP responses, which have been shown to characterize stimuli with a high emotional load (Vernet-Maury *et al.*, 1996). The distribution of the verbal as well as the ANS basic emotions revealed that fear was almost exclusively evoked by the odor of eugenol and only in fearful dental subjects, probably reflecting the negative dental experience of these subjects. The influence of general emotional factors on the apparition of dental fear has been questioned in several studies (Berggren and Carlsson, 1985; Kleinhauz *et al.*, 1992) which showed that the initial dental fear seems to be only weakly related to patients' general emotional reactions. Berggren *et al.* (1997) recently confirmed that most psychometrically assessed emotional reactions of patients suffering from severe dental fear were within the normal range, especially general anxiety and depression. Thus, it seems reasonable to relate dental fear to past negative dental experiences rather than to a personality trait. It can thus be suggested that the odor of eugenol, spontaneously identified as the typical odor of the dental office, evokes unpleasant feelings such as anxiety, fear or pain, experienced during painful (or potentially painful) dental care on vital teeth.

In conclusion, the results of this study demonstrate that the transcription of the patterns of ANS responses induced by the inhalation of odors allows the association of an olfactory sensation to a basic emotion, confirming the strong relationship between olfaction and emotion. Concerning eugenol, this odorant was shown to evoke negative basic emotions, especially fear, in dental fearful subjects, thus confirming the potential role of odors as elicitors of emotional memories. This study also supports the possible influence of the ambient odor, due to eugenol, impregnating the dental office in strengthening negative conditioning toward dental care. This could be avoid by eliminating the odor of eugenol in the dental office. The possibility of masking it by a pleasant and relaxing odor, such as lavender (Ludvigson and Rottman, 1989; Lawless, 1991), should be considered.

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