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Creation Perspectives of Perfumery in the Year 2000

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According to Webster's dictionary,[1] a perspective is "...the aspect in which a subject or its parts are mentally viewed." Thus, this paper is dealing in the first place with a vision. However, in order to be credible, a vision has to be based on the analysis of actual studies, tools and trends. Therefore, quite an extensive discussion of current approaches and instruments is given here, and yet the presented vision is far from complete.

Application segments will only be quickly mentioned and a few remarks added about application-oriented developments and about raw materials here. The size (turnover-wise at the end of the 80s) of the four application segments was as follows: fine frangrance (20% of the total), cosmetics and toiletries (25%), soaps and detergents (40%), and household and industrial products (15%). These segments are here to stay, and even their size will increase over the 90s at a comparable rate—in reality by a few percent every year if everything goes well.

New raw materials will be specifically designed in view of their application in a given segment, and new and old application-oriented parameters of raw materials will be precisely determined. Such parameters are, for example, substantivity and water-solubility, which are to some extent interdependent and have to be carefully balanced for specific applications in the four segments; biodegradability which mainly plays a role for household and industrial products and for soaps and detergents; deodorant efficacy which is mainly important for cosmetics and toiletries, etc.

The black theatre in Prague

However, for the sake of concentration, our focus is on the message: Progress in understanding the mechanisms of olfaction will add new dimensions to the intellectual space in which creativity can take place.

Of course, this will not a priori make life easier for perfumers, as the famous Edmond Roudnitska says in the book *Perfumes: Art, Science and Technology*, "It has often been said that great masterpieces are simple, that simplicity keeps the artist on the track to success. This is all the more true because materials have a complex nature."[2]

Notwithstanding the fundamental truth of that statement, even Roudnitska would certainly advise us to explore the new ways of thinking when science opens up the horizon, and he has actually said elsewhere in this book that the corresponding input from research is "more than welcome." Thus, we might start with a simple attempt of the definition.

"Odor is a property of objects, which allows living creatures to perceive and to characterize these objects by means of the sense of smell."

For the sake of comparison, "color" shall be defined as well: "Color is a property of objects, which allows living creatures to perceive and to characterize these objects by means of the sense of color vision."

Well, everybody is probably in full agreement with the term "to characterize," but perhaps not with the term "to perceive." Therefore, this point shall be quickly addressed.

In a black and white picture of the famous black theatre

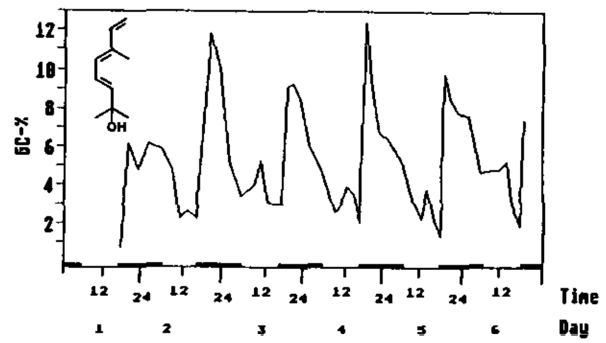
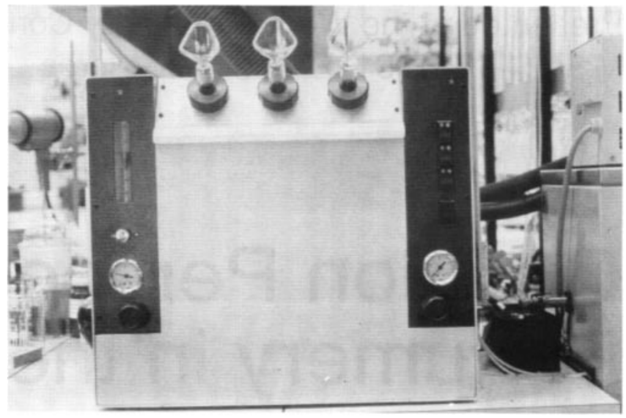


Figure 1. White Hyacinth: circadian rhythm of ocimenol emanation.



The olfactometer constructed by Givaudan

which existed in Prague—and it is, of course, really a pity that we do not see the colors of the robe the beauty on her flying carpet is wearing,—we can still at least see her, even without colors, but we do not see the additional actors on the scene who are carrying the carpet and who are totally hidden just because they are wearing black in front of a black background. Thus, the wrong color in the wrong place could kill the most beautiful illusion...and the wrong perfume can analogously do the same! Of course, this is just one of the parallels of color vision and olfaction, and this statement will be substantiated below.

Understanding the Mechanisms of Olfaction

Factors which influence the perceptibility of odors or of sensory signals in general are: the "type" of the odor or signal (and it has just been demonstrated that its differentation from the background is influencing perception), the intensity of the signal, the volume or space distribution, and the time or frequency.

Everybody knows, on one hand, that there are time-dependent phenomena (we are at differing times smelling the top notes, the heart, and the "fond" of a composition on the smelling strip) and everybody feels on the other hand that there is a wealth of time-dependent phenomena which have barely been investigated by scientific measurements. Sure, Roman Kaiser started many years ago to investigate, by headspace analysis, the time dependence of the scent of flowers,[3] and he showed in many instances that the plants' metabolism changes with the daily rhythm. Figure 1 shows the daily rhythm for just one chemical substance in the hyacinth's headspace, and other substances have their peak where the ocimenol is at a minimum. Still, these measurements had to be obtained by an integration (or collection of substance) over a certain time. Therefore, we wouldn't recognize it if this curve were just the envelop of a finer structure.

Thus, there remains a lot to be discovered with regard to time-dependence at the level of the odorant signals; and the same is true for the level of perception. What is, for example, the time resolution of our nose for differing odors? We don't know, and we don't even master the basis, i.e., the influence of sniffing behavior. This involves volume, as well as time-dependence of odor perception. Probably that is why the late Morley Kare, former head of the Monell Research Institute in Philadelphia, elaborated so much on this point in the chapter he provided (together with Avery Gilbert) in the already mentioned book.[2]

The discussion of the factor "time" shall be concluded by mentioning habituation, i.e., the development of tolerance against odors. An in-depth understanding of this phenomenon will certainly be a key on the industry's way to dynamic perfumes to a rationally engineered time-dependent release of a variable fragrance.

Having reached that far out into the future, the present time shall now be addressed. The factor "volume" shall be omitted, and the perception of odor intensity shall be discussed. The instrument under discussion is one of the olfactometers Givaudan has constructed, and is being used in-house. Equal streams of air come out of the three glass noses, and a randomization program loads one of the streams with a given concentration of the odorant under investigation. The panelist has to identify the odorant-containing stream, and the process then starts again with a lower concentration. This is repeated down to the odor perception threshold level where the panelist starts to make mistakes. The same experiment is performed with a whole panel, and reliable average perception threshold values are the result. They are used as a first approximation for the potency of individual odorants and are very useful as a tool for the perfumer, and it will soon become clear why one is speaking of a first approximation.

Modifying the above instrument by adding a knob has led to new possibilities. The additional knob allows the panelists themselves to regulate the concentration of one odorant presenting stream and to adjust it as accurately as possible to another stream containing the same odorant which the experimenter has set at a given (above threshold) concentration. Thus, the third glass nose is actually not playing a role in this case, and the panelist is only comparing the variable concentration and the steady target. Obviously,

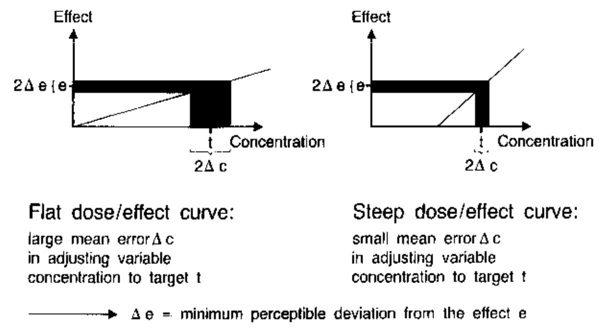


Figure 2. Dose/effect curve of odorants.

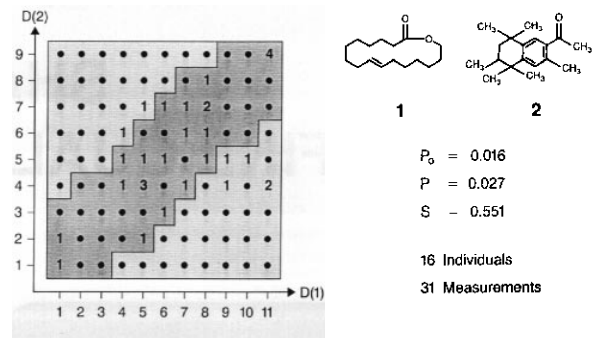


Figure 3. Threshold panel correlation matrix, in sixteen volunteers, with two similar substances.

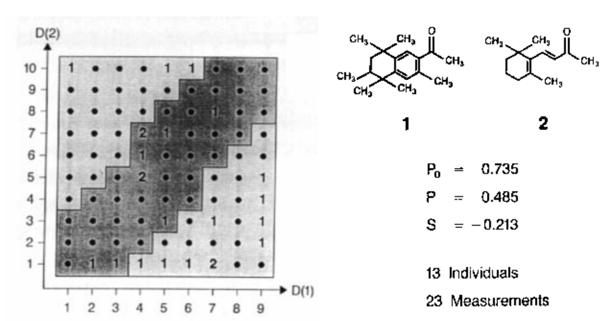


Figure 4. Threshold panel correlation matrix, in thirteen volunteers, with two clearly dissimilar products.

the larger the panelists' mean deviation from the target concentration, the smaller the influence a given concentration difference has on the odor. This is explained by Figure 2 which shows on the left that one would expect a large mean deviation Δc from the target concentration t in the case of a flat dose/effect curve, and on the right that the expected mean deviation from the target becomes smaller in the case of a steeper curve. And it is, of course, assumed that the same minimum difference Δe of the effect is just perceivable for the panelist. The whole curve can be measured by repeating the experiment with differing target concentrations t.

Very probably perfumers will, in future, not only consider the perception threshold value, but also the slope of dose/effect curves when judging the potency of odorants. In addition, synergistic effects (in terms of intensity boosting) will, for the first time, become reliably measurable through determining the increased slope of the dose/effect curve of the synergistic mixture.

Figures 3 and 4 shall demonstrate that simple perception threshold determinations can, in principle, even be used to identify basic odor types. It will become apparent later on that the identification of basic odor types might have more than a purely academic interest.

The first matrix (Figure 3) represents the results obtained in the perception threshold determination with a panel of 16 volunteers who all participated repeatedly in the threshold determination with two similar substances, the musks **1** and **2** (ambrettolide and Fixolid). Thus, the dilution steps (to be more precise, the concentration steps in terms of starting at the lowest observed individual threshold value and of every time doubling the concentration of the respective substance) are indicated on the horizontal and vertical axis, respectively. Every point in the matrix is, therefore, corresponding to a pair of concentrations. One finds a nice correlation: panelists who are sensitive to substance **1** (who have a low perception threshold value) are also sensitive to substance **2** (e.g., the "1" on the lower left indicates that there was one panelist who perceived substance **1** at the first and substance **2** also at the first concentration step). The value of P or P_0 below 0.05 indicates that there is more than 95% probability for the correlation to be real and not accidental, and the highlighted area along the diagonal illustrates the mean experimental error of the threshold determination.[4]

Figure 4 represents a similar experiment as above, but now with two clearly dissimilar products (a musk and an ionone). Obviously, no correlation is found anymore, and there are many off-diagonal results. Mathematically, the absence of a positive correlation results in a high value of P or P_0.

Thus, the similarity or dissimilarity of odorants becomes a quantiatively measurable dimension which can be expressed as a correlation factor. It must be added that our industry will, in future, be much more aware of the significant inter-individual variations which exist with regard to the sensitivity for basic odors.

Yet another instrument shall now be quickly mentioned: Givaudan-Roure's so-called MOB (multichannel olfactive blender). This instrument is used by perfumers to mix odorant containing gas streams rather than liquids. Thus, the perfumer can just turn knobs and very rapidly smell many variations of mixtures, and he can mix as liquids only the ones that he chooses. The computer attached to the instrument does not only visually represent on the screen the individual components' contribution to the odor, but

Givaudan-Roure's multichannel olfactive blender

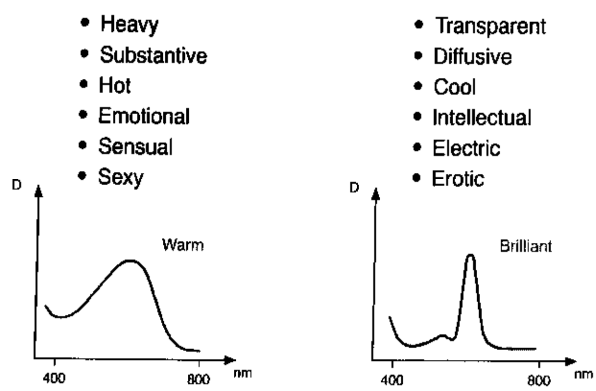


Figure 5. Brilliance and warmth of odors: Comparison with colors.

also calculates the liquid composition which corresponds to the headspace as perceived at the instrument's nose.

The MOB was developed on the basis of a very old conceptual idea, and more than a decade of research and experience with regard to constructing olfactometers. There is no question that in the year 2000, perfumers will use this type of instrument much more frequently than today.

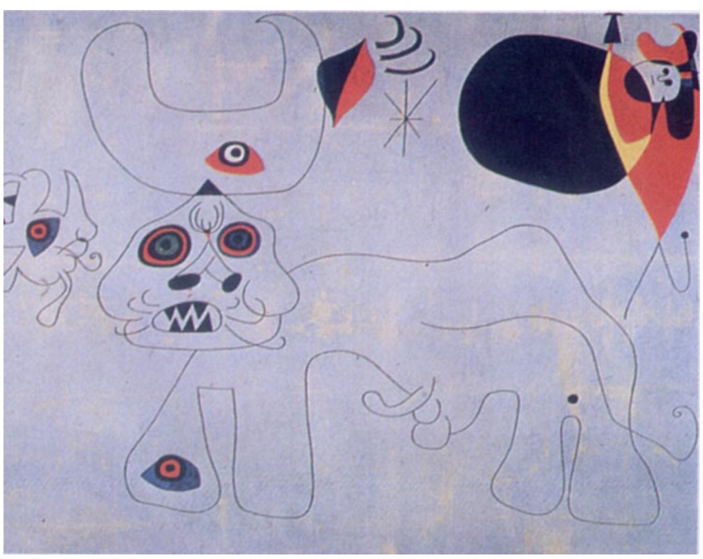
Coming back to the perception of signals, color vision has to be mentioned again briefly. In this case, the receptor apoproteins are known as well as the cofactor. Thus, there are no more than three-color vision receptor protein types having seven helical trans-membrane domains, which allow us to distinguish all the nuances of the whole color spectrum from light yellow to dark blue. This had been predicted on the basis of the study of different types of partial color blindness long before the proteins were identified,[5] which reminds us, of course, of the partial anosmiae just discussed and of the theoretical possibility to predict the basic odor types on the ground of panel correlation matrices.

One cannot forecast that sensory measurements will beat molecular biology in the case of olfaction—in spite of the fact that not even the existence of this type of olfactive ligand binding proteins was regarded as established up to a few months ago when Linda Buck and Richard Axel published their paper in Cell.[6] This paper makes it at least very probable that a large family of seven trans-membrane domain proteins is responsible for olfactive reception. Thus, the (rather obvious) speculation presented about a year ago[7] is slowly being accepted as a fact. Here, it should be made very clear: we are, according to Buck and Axel, not dealing with seven receptor proteins, but with many receptor protein types which all contain seven trans-membrane regions!

Brillance and Warmth

It is hard to predict the main application that will result when the question of the number of olfactive receptors is one day solved, just as the color TV was invented long after the development of a valid theory for the sensory system involved. We will discuss a more design-oriented aspect of color vision and try to approach olfaction in similar terms. Of course, one has to be aware of the preliminary character of this discussion.

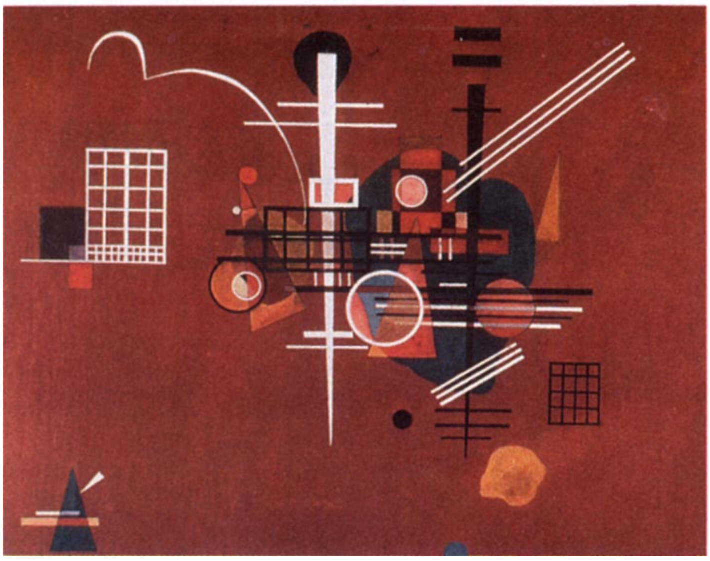
Colors cannot be characterized only as blue, red, yellow, green, etc., but also as intense or faint, and finally, as warm or brilliant; and it is mainly the last couple of terms which shall now be addressed. Modern painters are (or have been) very much aware of these qualities. "Corrida," the very cheerful painting by the famous Spanish painter Joan Miró, demonstrates how modern painters are very consciously working with brilliant notes in their compositions. The very intense brilliance of the red in the upper right hand corner of this painting is marvellously contrasted by the intense brilliance of yellow, the small amount



Joan Miró's "Corrida," 1945
(oil on canvas, 114 x 146 cm)
Paris, Musée national d'art moderne

of black and very warm blue, and the large excess of the low intensity brilliance of the blue which is forming the background!

"Dull red" is one of the famous Russian Wassily Kandinsky's masterpieces, and one immediately recognizes composing similarities and differences if one thinks of "Corrida" by Joan Miró. Again, there is a balanced dose of brilliance (in this case white which can be called the extreme of that quality) and, again, this brilliance is systematically contrasted; but here the contrast is not brilliance—it is warmth, and the highest intensity of warmth is forming the background!



Wassily Kandinsky's "Dull red," 1927 (oil on canvas, 66 x 76 cm)
Paris, Maeght Gallery

Thus, it is intuitively understandable what brilliance and warmth are with regard to colors, i.e., the painter's raw materials, but these qualities are not yet rationally mastered with regard to odorants or perfumes. Our mastering them with regard to olfaction would add a dimension to the space which encompasses the perfumer's creative freedom.

The lower part of Figure 5 shows how brilliance and warmth can be distinguished by physics and how they can be rationalized in terms of receptor activation: brilliant colors which have narrow visible absorption curves are activating the three receptor types in a strongly unbalanced way,* whereas warm colors have broader absorption curves and are more evenly activating the three receptors mentioned. This leads to an obvious question: can one address the perfumers' palette of raw materials in similar terms? Before answering, the reader's attention should be drawn to the upper part of the figure, which takes the reader to a totally different level, i.e., the level of associations or of the psychological counterpart to the just mentioned physical or physicochemical qualities.

Of course, there is no unequivocal translation of warmth or brilliance into the list of words like heavy, substantive, hot, emotional, sensual, or sexy on the left or words like transparent, diffusive, cool, intellectual, electric, or erotic on the right. Rather, this is very personal and in addition, dependent on the environment of the word or the color. The presented approach also differs very considerably from Mensing's or H&R's[8] as the centerpiece of their theory was not a phenomenological sensory investigation, but rather the psychological level which was intuitively and empirically used as the link of two sensory systems.

Figure 6 illustrates how odors could be defined as warm or brilliant, provided the basic odor types or the receptors were known. Obviously, odors which result in an uneven or selective activation of specific receptors would be classified as brilliant, and odors which lead to a broader and more balanced activation would be classified as warm. This is analogous or, to be very precise, inversely proportional to the situation in color vision as the presence of sunlight, but the absence of odor has been taken as the respective standard.

In comparing odors and perfumes or colors and paintings, it can be said that it is mainly time which contributes variability to perfumes, and space which contributes variability to paintings. Thus, one would say that a given perfume has, e.g., a brilliant top note and a warm heart.

Of course, one could hope that the GC of a perfume or a flower scent (Figure 7) would tell us something about the odor's complexity, but this does not necessarily have to be true as the threshold values of odorants can easily differ by factors of many thousands and as even single substances can contribute to either brilliance or warmth. Thus, it is rather accidental that the simple headspace[9] of the orchid *Angraecum bosseri* actually corresponds to a fragrance which we would intuitively clas-

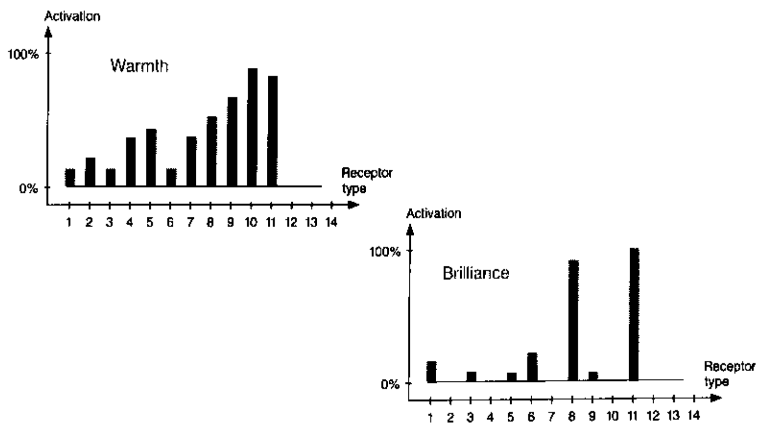


Figure 6. Olfactive counterpart to warmth and brilliance.

*"White" forms the only exception in this respect as it is actually fully activating all the receptors, but it is not a color in the true sense of the word.

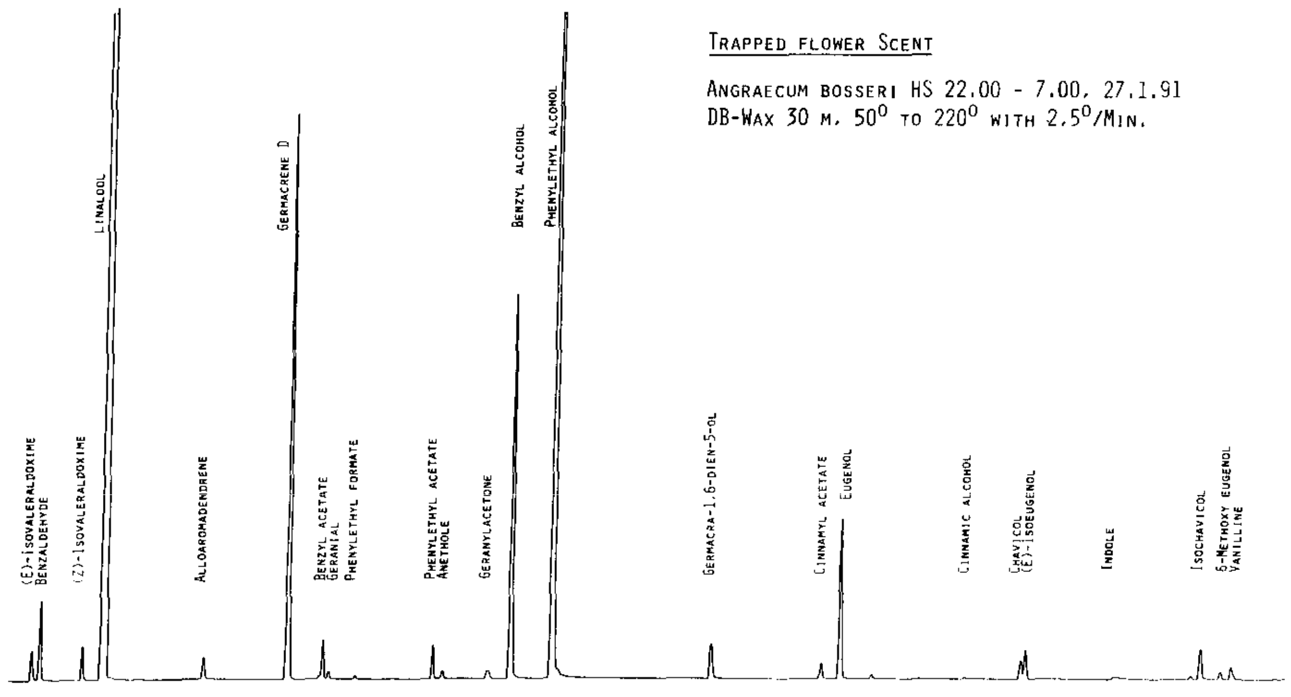


Figure 7. GC of the orchid *Angraecum bosseri*.

sify as brilliant or call white-floral, homogeneous and transparent, and which we could interpret as an accord of linalool and aromatic alcohols and their derivatives on the one hand and of eugenol and derivatives, as well as vanillin and indole on the other. It is tempting to take it as a sign of nature's intrinsic harmony that this fragrance is emitted by a beautiful and elegant white orchid and that it is exclusively emitted at night.

The very colorful epiphytically growing orchid *Cattleya dowiana* from Costa Rica represents quite a contrast to the one just mentioned, and its fragrance is again matching the flower's appearance: a lively top note which is reminiscent of lily of the valley, but also of lemon and rose above a rather heavy spicy-floral accord our intuition would definitely classify as warm. The GC of the *Cattleya dowiana*[9] (Figure 8) is a bit more complex than the one we have seen before, still it is similar and surprisingly simple. Thus, warmth or brilliance cannot be judged just on the ground of a quick look at the GC of a headspace. Rather, a lot of know-how of the components' threshold values, main odor types, and individual warmth or brilliance is required. This is also the reason why the preparation of high quality headspace reconstitution requires much more than just a chemical analysis.

Figure 9 illustrates how a group of perfumers, in a blind test, have individually described the odor of a single substance, geraniol, which we would call brilliant if we assumed that the thesaurus of the about thirty words they used really reflected the main basic odor types or receptors—this is probably neither true nor totally wrong. The bars on the diagram represent the average of the relative intensities the perfumers had attributed to the selected terms. The substance's brilliance is seen as a very prominent highest bar which corresponds to 55% of the total.[10]

Figure 10 displays the result of a fully analogous experiment with phenylethyl-alcohol, a substance which we would tend to call warm, as the highest bar represents no more than 31% of the total (it must be added that the olfactive purity of the two substances was carefully checked before the test).

It can be expected that the type of diagrams shown in Figures 9 and 10 will, in the future, become increasingly meaningful and useful, especially if the perfumers succeed in further adapting to the psychophysical realities and improving the thesaurus of descriptors they are using.

Conclusion

A number of predictions have been made here, highlighting the perception-oriented dimensions. It can be predicted that perfumers will consider habituation effects which will become the subject of sophisticated measurements and be more thoroughly understood, and that they will accordingly create for dynamic perfume release. It can also be predicted that creating by mixing odorant gas phases will become more practical and more frequently used, that synergy will not only be understood in hedonic, but also in technical or psychophysical terms, and that quantitative knowledge of odor types and the individuality of odor perception will play an increasingly important role.

Finally, it can be foreseen that perfumers will address odor intensity in differentiated terms and consider the slope of dose/effect curves. These developments will influ-

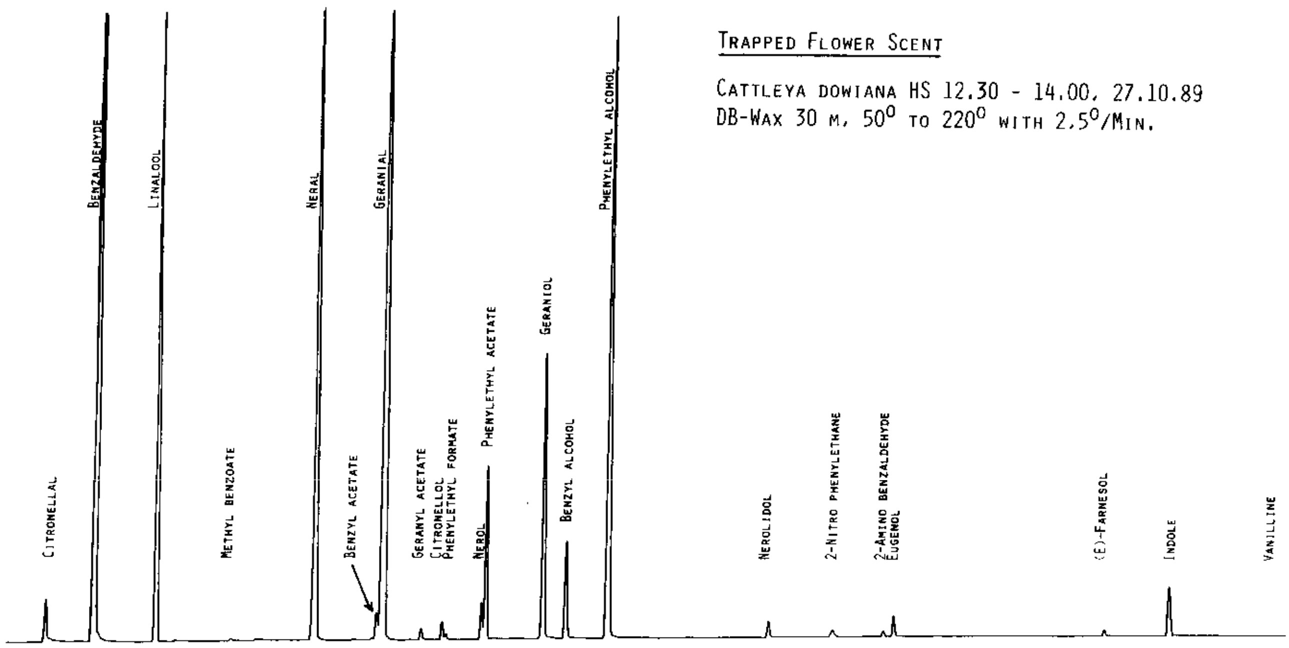


Figure 8. GC of the *Cattleya dowiana*.

ence the technical performance of perfumes, as well as the designing process, and it will be possible to literally translate sensory dimensions like brilliance and warmth, from fields like color vision, and to add them to the intellectual space in which creativity can take place. This will be stimulating, but it will not substitute the perfumer's intuitive creativity; and it can and will not be the researcher's goal to conquer the field of artistic design.

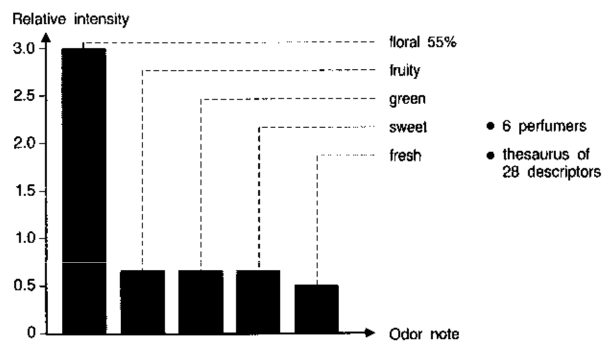


Figure 9. Geraniol: Mean relative intensity of odor notes.

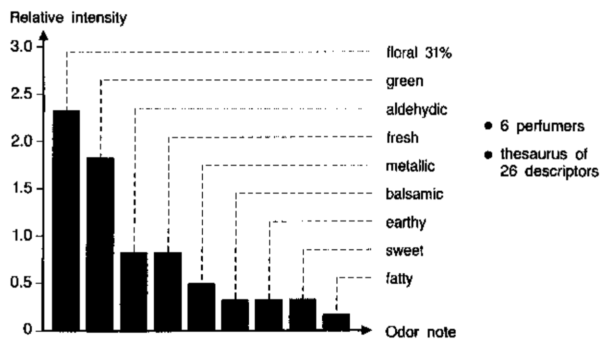


Figure 10. Phenylethyl-alcohol: Mean relative intensity of odor notes.

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