Kinds and intensities of odors

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The two basic physical properties of odors are kind and intensity. The kind of odor is usually expressed as 'like something' e.g. like roses, like cucumber, or fish-like or like one of a thousand other things such as apples, pears, oranges, lemons, thyme, sage, parsley, fennel, pepper, ginger, cloves, cinnamon, mild cheese, Dutch blue, gorgonzola or camembert, or, if you are a chemist, like hydrogen sulfide, pyridine, ethyl mercaptan, or butyl alcohol. All of these substances have quite different smells, all fairly well known and recognizable. This is a natural approach to the task of defining odor quality and it is a good way out.

You can take any four odors and attempt to say how much of each of the four your chosen experimental odor has, as did Crocker and Henderson.[1] They chose the four standards: fragrant, acid, burnt, and caprylic, and assigned numbers out of 8 to represent the content of those qualities. Rose was given the number 6423. Many people have tried the method and some say that it gives useful results. As the author sees it, it probably does, but there is no special reason why the four qualities chosen should have been selected. One might just as logically have used Henning's six: spicy, flowery, fruity, resinous, burnt, and foul[2] or Zwaardemaker's nine: ethereal, aromatic, fragrant, ambrosial, alliaceous, empyreumatic (slightly burnt), caprylic, repulsive, and nauseating.[3] There is not a great deal of common ground here except that all three selections include burnt. Whichever four, six, nine, or one hundred standards you choose, you cannot hope to cover every nuance of smell.

The concept of a few primary odors is attractive. When I started to work on olfaction some thirty or forty years ago, I spent a lot of time looking for these primary odors. I thought that halogen was one, and I noticed recently that at the International Symposium, held in Fukuoka, Thiemer presented a paper entitled "The primary odor—urine"[4] and Amoore a paper entitled "Six of the primary modalities of man . . . "[5] There seems to be not a lot of common ground to begin with. I know that urine is a unique odor and has a specialized advertising function to perform. I know that all Amoore's work makes people think and that is fine. I have read and reread Yoshida's paper "Studies in psychometric classification of odors" parts 4 and 5.[6] He has contributed something new in his analytical methods but, as I see it, what he has found is that there is no basic classification that he could discover. He might not agree. But all the papers I have read about fundamental odor classification have led me to the same conclusion: that no such classification has much to offer. In all the work I have done on odorants, I cannot remember ever coming across two substances which had indistinguishable odors. You have only to read the work of Adrian[7] and Le Gros Clark[8] to reach this conclusion, although neither of these two famous warriors has ever made the statement that no two receptors are the same.

It is well established that there are approximately

Perfumer & Flavorist Volume I, Number 5

October/November 1976

Founded in 1906 as The American Perfumer

10^8 receptors in man and that each has an individual connection to the olfactory lobe. There is some grouping here and the number of output fibers going to the cortex of the brain may be about 5×10^4. It hardly matters which number you take, either way the number of possible different odors is so large that for all practical purposes it is infinite. If you have 10,000 different fibers and any one of them can fire then that accounts for 10,000 smells. If two are fired at one time it is 5×10^7 different combinations. With three fibers firing at once the number of different possibilities is more than 10^{11}. The total with n firing at once when n lies between 1 and 10,000, would be astronomical. At least we can say that with the known olfactory equipment of man, an infinite number of different smells is likely. And so in our experience do we find there is no end to the number of smells. And except for empirical purposes, it is a waste of time trying to classify them. I, for one, do not subscribe to the view that there is a specific receptor for each and every odor. Rather, I think that all the receptors may be slightly different but that any one smell will probably excite a number of them. It is very improbable that any two different smells will excite the same group. Perhaps a large number of receptors will be excited by the acetone smell, but some will be highly excited and others only marginally excited, with all possible intermediate degrees of excitement. That is what I read into the work of other people and I find some support for this view in my own work on the instrumental detection of smells,[9] in which adsorbent films are used to sense the presence of odorants. In general, any one kind of film will respond to many odorants, to most only slightly or even marginally, to others fiercely, like a famished animal eating.

The easiest and most natural classification of odors is into one group which says "yes, eat me" and another group which says "don't." One can of course group all the rose-like odors in one class, all the spicy odors in another, and the results are not without meaning or use. But they are not what we have all been looking for: some meaningful basic division.

Similar Odors

This is not to say that it is not useful to know how similar two different odors are. This knowledge has industrial applications and is certainly a useful prologue to a study of the relation between constitution and odor. At the very least it is interesting to be able to say how similar the smells of two different substances are and to be able to put a number to the degree of similarity.

If there are two odors that are similar to one another, the presence of one will cause adaptation on smelling the other. Adaptation is the most easily measured of physical phenomena that is closely related to similarity of smell. For example, when sweet peas are held to the nose, their smell weakens with time, but if when their (the sweet peas) odor is very weak a rose is smelled, it (the rose) by contrast smells strongly. The odors of sweet pea and rose are quite different and there is little adaptation of one for the other. If however two substances are used which obviously have somewhat similar smells, the adaptation may be much greater. Benzaldehyde and nitrobenzene constitute a well-known pair, the smell of the latter is coarse and rougher and reminiscent of a student's organic laboratory, but benzaldehyde is smoother and nutty. Both smell rather like almonds. People who are at all familiar with them cannot confuse them, but I found that beginners smelling them one at a time (not able to compare them) could confuse them.

	Threshold Concentration (%)
(1) Benzaldehyde*	0.05
(2) Nitrobenzene*	0.05
(3) Benzaldehyde after a prior sniff with benzaldehyde	0.50
(4) Benzaldehyde after a prior sniff with nitrobenzene	0.40
(5) Nitrobenzene after a prior sniff with nitrobenzene	0.50
(6) Nitrobenzene after a prior sniff with benzaldehyde	0.10

* dissolved in propylene glycol and smelled alone

Of these experiments (1) and (2) are unadapted, (3) and (5) are of homogeneous adaptation, and (4) and (6) are of heterogeneous adaptation. The experimental technique has to be watched carefully; it is described fully in the original paper[10] and in the author's textbook.[11] In brief, the two heterogeneous adaptation concentrations are multiplied together and divided by the product of the two homogenous adaptation concentrations. The square root of this expression is termed the coefficient of likeness. In the case of nitrobenzene and benzaldehyde,

$$\left(\frac{0.4 \times 0.1}{0.5 \times 0.5}\right)^{\frac{1}{2}} = 0.40$$

The method is logical; it is dependent on the ratio of heterogeneous to homogeneous adaptation. The maximum possible value of the coefficient is unity. Some observed values are shown in Table I. The figures lend support to the view that in the immense range of odors, two that are even noticeably similar occur only infrequently.

Odor Intensity

The concept of odor intensity is familiar. We easily recognize n-butanol and amyl acetate as having intense odors, and methanol and coumarin as having odors that are relatively weak. Just as in the study of odor likeness, we can use adaptation observations to make a measure of the intensity of an odor. We define odor intensity thus—the enhance-

Table I

Coefficients of Likeness of Odorant Pairs

Odorant Pair	Coefficient
Amylacetate and butyl acetate	0.89
α-Ionone and β-ionone	0.45
Nitrobenzene and benzaldehyde	0.40
n-Propanol and isopropanol	0.27
n-Butanol and methanol	0.19
Acetone and methanol	0.12
Isopropanol and diacetone alcohol	0.07
Acetone and diacetone alcohol	0.04

ment of odor's threshold concentration, caused by one previous sniff of the undiluted odorant. For example, if the threshold concentration of acetone diluted in water is, as it is, 0.03%, and the threshold concentration of similar solutions of acetone is 5.0% just after taking one previous sniff of undiluted acetone, then the enhancement is 5.0/0.03 or 167, and we say that the odor intensity of acetone is 167. Values for other substances are shown in Table II. All of the odorants fall into acceptable places, the most intense have high values and the weakest have low values. Details of the experimental work are given in the original paper[12] and in the author's textbook.[11]

Table II

Evaluation of Odor Intensity

Odorant	Kind of Odor	(%) Threshold Concentration	Threshold Concentration (%) after one prior sniff of undiluted odor	Intensity
Allylcaproate	Pineapple	0.00002	0.10	5000
Pyridine	Rank, tobacco-like	0.00005	0.07	1400
n-Butanol	Fusel oil	0.00500	1.00	200
Clove Oil	Cloves	0.00300	0.50	170
Acetone	Characteristic	0.03000	5.00	170
Amyl Acetate	Pear drops	0.00200	0.30	150
n-Butyric acid	Sour, bitter	0.00100	0.10	100
α-Ionone	Violets	0.05000	1.50	30
Benzaldehyde	Nutty	0.05000	0.50	10
Benzylamine	Fishy	0.30000	0.50	2

Of other attempts to put a number to intensity of odor, none has been outstandingly successful. Beck, *et al.*[13] tried to compare the intensity of odor of different substances with that of diluted heptaldehyde. Results for a single observer were fairly consistent but between one observer and another there were great discrepancies, so great that the several observers seemed to be comparing different properties. It is always unsatisfactory to say which of two unlike things, such as a red light and a white light, is the stronger. There was another somewhat similar paper by Kruger, *et al.*[14]

In a nutshell, the primary difficulty is that we ask too much of our assistants and colleagues. They are not born with the sensory and mental equipment to analyze kinds and intensities of different odors. The thing to do is to arrange one's experiments so that the only question asked is "can you smell this?" and the only answer "yes," "no," "doubtful." It is useless to ask them about relative intensities and qualities of different substances. In the author's experimental work described above, the only question asked was "can you smell this?" A straight question gets a straight answer. If you have engaged in odor testing sessions, you know how exhausted you feel after half an hour of concentrated effort. Working near the threshold level is very difficult indeed. There can be agonies of indecision. I have always told my observers that it is their first snap impression that counts and is usually right. The chemical senses in our bodies are wonderfully designed and will come out with "I can smell it" or "I can't smell it" instantaneously.

Acknowledgment

This paper was presented at the Japanese Symposium on Taste and Smell, August 29, 1976, in Osaka, Japan.

References

1. Crocker, E. C., and Henderson, L. F., Analysis and classification of odors, Amer. Perf. **22**, 325, 256, 1927.
2. Henning, H., Olfactory prism, Der Geruch, Leipzig, 1916.
3. Zwaardemaker, H., Die Physiologie des Geruchs, Englemann, Leipzig, 1895.
4. Theimer, E. T., The primary odor—urine, presented at Intl. Symp. on Food Intake and Chem. Senses, Fukuoka, Japan, September 1-4, 1976.
5. Amoore, J. E., Six of the primary modalities of man. Experimental evidence and possible significance, presented at Intl. Symp. on Food Intake and Chem. Senses, Fukuoka, Japan, September 1-4, 1976.
6. Yoshida, M., Studies of psychometric classifications of odors, parts 4 and 5, Jap. Psychol. Research **6**, pp. 115-124, 145-154, 1964.
7. Adrian, E. D., The physical background of perception, Oxford, 1947, pp. 60-61; Brit. Med. Bull. **6**, 1534, 1950.
8. Le Gros Clark, W. E., Proc. Roy. Soc. B. **146**, pp. 299-319, 1957.
9. Moncrieff, R. W., An instrument of measuring and classifying odors, J Appl. Physiol. **10**, 4, pp. 742-749, 1961.
10. Moncrieff, R. W., Olfactory adaptation and odour likeness, J. Physiol. **133**, pp. 301-316, 1956.
11. Moncrieff, R. W., The Chemical Senses, 3rd ed., Leonard Hill, London, 1967, pp. 154-158, 161-169.
12. Moncrieff, R. W., Olfactory adaptation and odor-intensity, Amer. J. Psychol. **70**, 1, pp. 1-20, 1957.
13. Beck, L. H.; Kruger, L.; and Calabresi, P., Observations on olfactory intensity, Ann. N.Y. Acad. Sci. **58**, pp. 225-238, 1954.
14. Kruger, L.; Feldzamen, A. V.; and Miles, W. R., Comparative olfactory intensities of the aliphatic alcohols, ibid, **68**, pp. 386-395, 1955.