Odor Memory

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Verbal Identification. Our first work on this problem of the ability of human observers to identify odors verbally began in the late 1950s. The mathematical information theory developed by communication engineers then played an important role in sensory psychology (Engen, 1961). Human sensory ability was largely viewed as a processing device transmitting information about the energies in the environment via the various sense modalities and encoding it into memory. Memory capacity could then be considered the main factor limiting the sensory ability of the observer. One advantage of this approach is that different modalities can be compared on the basis of their information transmission capacity despite the fact that different kinds of energy are involved. Miller (1956) summarized this research and concluded that as far as unidimensional energies or stimuli, such as the pitch of sound varying only in frequency, were concerned, man was able to identify seven different levels without confusion regarding their rank order from low to high.

Our first effort in such information measurement in odor intensity showed that an average intelligent observer without any special training or experience could identify only three different levels or concentrations presented separately. Only a highly practiced observer could reach a maximum near the low level of five, Miller's "magic number." That is, if more than five levels were presented one at a time to be identified by the rank order of its odor intensity, the observer would make errors by confusing the intensity ranks. The potential importance of experience, a variable of special interest in the case of perfumers and flavorists, remains an unsettled issue though a few papers have provided valuable information (Jones, 1968; Desor and Beauchamp, 1974). Our research has been directed toward the typical observer, or the average healthy human being, and norms for the textbooks concerned with the olfactory system rather than with training or selection of expert noses.

The work on intensity did confirm the popular notion that man's ability to make absolute judgments of odor intensity was poor compared with similar judgments in other modalities. Our main interest here is in the even more popular notion that man's ability to recognize odors is enormous. Enthusiastic promoters of the channel capacity of the nose claim that man can identify at least 2,000 odors and the expert perhaps as many 10,000 (Wright, 1964). It is important to define carefully what is meant by identification in this case and to specify what the observer is asked to do. There is no experimental data demonstrating such great capacity in the literature. One can only find anecdotes like the one about the "Million Dollar Nose" of Ernest C. Crocker.*

The experimental task in our laboratory follows. The subject was first presented the odors together and he/she could use as much time as needed to get acquainted with them, including making comparisons to clear up potential confusions of similar odors or anything else that might interfere with later recognition. The number of different odors ranged from five to thirty-six in different experiments. When the subject was ready, the experimenter wrote down the name the observer assigned to each odor.

The second part of the experiment tested the subject's ability to reproduce those previously assigned names or labels when each odor was presented singly with all cues other than odor removed. The results showed the average subject could identify nearly perfectly a set of odors numbering up to 16, but for larger sets more and more errors were made. In terms of information theory, nevertheless, the amount of information transmitted remained constant at 4 bits/stimulus, or 16 categories when information is measured in terms of $\log_2 1/p$, where p is the probability of occurrence of each stimulus in the set. The bit stands for binary digit measured on a log scale to the base 2 such that the antilog provides an index of the number of stimulus categories (odor qualities for the present case) the observer can use without such confusions.

The constancy of this measure for different numbers of odors in the test indicates that limitation is in the olfactory system rather than the result of some special confusion associated with the number of odors presented. In other words, it is not that the system breaks down when challenged but that it reaches an upper and asymptotic limit. This limit was clearly much less than expected, but it has stood up with replication of the experiment. It is also in line with performance of multidimensional stimuli in other modalities (such as tones) varying several attributes rather than just one (Miller, 1956). One should note that the result was obtained with a set of odors selected for diversity rather than familiarity or ease of recognition on some other basis. Such variables do affect the results, of course. When in one experiment only acetates, aldehydes, and other sweet or fruity smelling compounds were presented, the performance went down to 14 categories (Engen, 1961). A similar experiment with highly distinct and familiar as well as extremely pleasant and

* The Saturday Evening Post, September 29, 1951.

unpleasant odors using highly trained observers improved the score significantly (Desor and Beauchamp, 1974). However, our own attempt to maximize performance by presenting 16 of the diverse odors each at three levels of intensity to combine the ability to transmit information about intensity and of quality produced essentially no gain. In that case perception of odor quality seemed to dominate (Enger, 1961). We are not interested in determining the maximum performance or to train observers to be as efficient as those with absolute pitch but to learn what an average person who happens upon an odor from an unknown source can do. For example, where there is smoke, there is fire; but how well can the average person identify smoke by its odor alone?

Odor Experts. Jones (1968) has reported a related experiment similar to ours, whose subjects were one "genuine chemist's nose" and two expert perfumers with long experience in the profession. Nevertheless, his results were quite similar to ours. Of the 45 familiar odors that the chemist himself selected to be in the experiment, he identified correctly 16. The two perfumers selected a total of 192 which were presented in sets of 16; for each of these sets they made 4 to 5 errors. One may be inclined to think that these subjects should do better, but as Turk pointed out (Jones, 1968, p. 143) this is not a representative test of what a perfumer does. Normally, he/she discriminates between perfumes or perfume ingredients and can predict the odor of their mixtures and the like. He is not typically asked to label odors in the absolute sense required in the second part of the experiment which produce the results under consideration here. In fact, we have shown that the use of preordained labels tends to diminish recognition scores (Engen and Ross, 1973). This evidently has been the source of much confused debate and therefore it seems worth repeating that the task in these experiments is *not* to study sophistication, training, or how well certain odors are recognized by the average person. There are, of course, individual differences in the subjects and, likewise, all odors are not equally recognizable. For example, all of our subjects recognized the unpleasant odor of pyridine with 100% consistency.

Pair Comparison Without Verbal Labels. The main limitation of the approach described so far was that it involves a special kind of memory storage based on previously learned association between an odor and a label. Encoding and retrieval of odors are not limited in that way. It is common that one encounter an odor and be certain that one knows it from a previous experience without being able to label it or say anything about one's previous experience with it. Lawless and Engen (1976) described this as a "tip-of-the-nose" phenomenon. Giving the person in that situation some relevant information about the odor quickly leads him to the correct label or association.

Naming odors is a very difficult task and must be one of the main reasons for the failure to achieve anything near a generally acceptable odor classification system. In one experiment (Engen and Ross, 1973), observers were presented a diverse set of 20 common odors at a time with instructions to identify each by label or short description of its use. The number of correct identifications was only 6.3 or 31.5% in groups of 40 observers or more. If one accepts good associations as possible answers, for example, describing amyl acetate as "airplane glue" or "fingernail polish," the score was 10.9 or 54.5%. Other results in the same study show that ability to recognize odors is superior to the ability to label single odorants. The poor verbal ability in this case may indicate that the connections between the centers for language and olfaction in the brain are diffuse (Mair and Engen, 1976).

In order to avoid this limitation we adopted a new method which may entail a conception of memory more nearly like the conventional one and without the requirement that the observer attach labels to the odors. The first part of this procedure again asks the observer to pay attention to each odor, and rate it for familiarity and pleasantness. (Surprisingly, whether or not he/she is told that there will be a later memory test is not important.) The second part of this procedure is quite different. Each of the odors inspected is now presented together with another odor which was not in the set. The subject is instructed to select the "old" one. The results are also different as shown in figure 1. In vision such pairwise discriminations between the "new" and the "old" is excellent and certainly far superior to olfaction when the second part of the experiment follows right after the first. While the present odor data are based on a selection of about 50 diverse odors, those from vision involved inspection of over six hundred such comparisons. Two specific things are especially interesting.

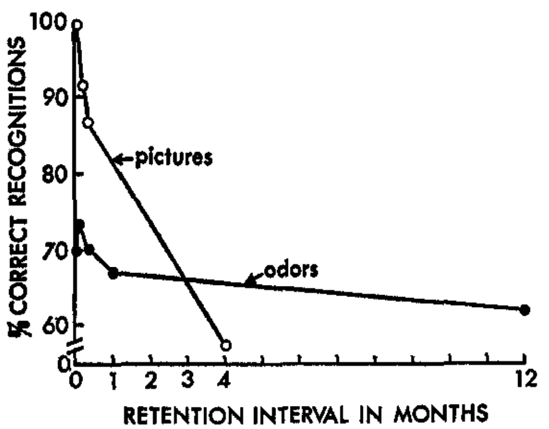

Figure 1. Mean percent correct recognition of an "old" stimulus in a test pair as a function of duration of the retention interval.

First, observe what happens as the time between inspection and the recognition test, the so-called retention time, is increased. In the case of vision the percentage of correct choices of "old" pictures decreases rapidly, especially in the beginning, following the classic form of the curve of forgetting. But in the case of odor the function is almost flat showing in one year a drop of about 5% which is of only borderline statistical significance. Even after that much time performance is still significantly better than the 50% chance level ($.005<p<.1$). The work by Lawless and Cain (1975) and Engen and Ross (1973) show that the number of variables does influence the overall level of performance but, beyond that, olfactory memory differs profoundly from visual memory with respect to the effect of time.

Second, the graph shows a striking difference between the two modalities in the initial level of performance. While in vision the performance just after inspection of the pictures is nearly perfect with 99.7% correct choices, in the case of olfaction it is less than 70% correct even though many fewer items were inspected originally. Our theoretical speculation is that pictures are more easily recognized after a short interval because they contain many distinguishable attributes such as size, color, and so on, that can be used in coding, while odors represent more unitary experiences. It is this aspect of odor experience artists refer to so often, for odors seem to be coded in an all-or-none fashion. This kind of coding is less efficient and may encourage errors in the early tests of retention, but it leaves odors resistant to confusions in later tests when pictures may be confused because they share a single attribute such as color.

In both cases, of course, the results are not from real-life situations. Some of the odors and some of the pictures may have been familiar from other occasions while others were experienced for the first time, and this could increase the difficulty of the task. It is the temporal difference between the two modalities which is of interest here rather than the absolute value of the scores.

This difference can be explained in terms of a standard psychological theory of forgetting which argues that forgetting is largely due to the effect of having to learn new responses or associations to the same item. The result is that retrieval of any one response will be hindered because of competition with other items. Reproducing the first rather than a later association made to the item is called retroactive inhibition. The present temporal data indicate that olfaction is relatively free from such interference. Odor memory is characterized by proactive interference or inhibition (Lawless and Engen, 1977); that is, it is difficult to overcome this first effect of an odor and learn other associations to it. Of course, such a memory system has survival value as illustrated by "bait shyness" or dislike of food which once made one sick through overindulgence or poisoning. Subsequent pleasant experiences with the same food do not readily change such preferences, for the odor readily recaptures the original feeling.

This difference in inhibition is also consistent with the many anecdotes about the excellence of odor memory. In fact, occasionally this kind of memory might be too good, as Boris Bedny illustrates in his short story, "Mosquitos" part of which reads as follows:

"The aromatic resinous smoke unexpectedly reminded Voskoboynikov of the half-forgotten scent of incense; his mother had been religious and had taken him to church in his childhood. He thought how unfortunate it was that his memory could retain this ancient smell, this early rubbish, to the end of his days, while it would forget many more recent and more important things. This subconscious contraband was like dirt tracked in from the outside: he'd always carry it with him even to communism itself, these old and unnecessary memories."

Is There Odor Recall? Odor memory is a robust psychological phenomenon, quite impervious to the effect of time. Yet it is not necessarily outstanding in terms of the number of items which can be committed to memory, and it would be overstating the case to conclude that odor memory is unique. The level of training and sophistication of the observer is one important consideration, and so is the nature of the task which defines how memory is measured. To my mind, it is a rather special ability pertaining to recognition rather than absolute recall or other cognitive abilities that might be characteristic of odor memory. A quote from Nobokov will illustrate the difference between recall and recognition.

". . . She used a cheap, sweet perfume called 'Tagore.' Ganin now tried to recapture that scent again mixed with the fresh smells of the autumnal park, but, as we know, memory can restore to life everything except smells, although nothing revives the past so completely as a smell that was once associated with it."

Some people claim they can upon command recall specific odors, others think not and argue that such memories consist only of sensory attributes from other modalities. For example, one can remember the color and shape of a lemon and even make grimaces associated with its sour taste without being able to conjure up the odor experience per se. Unfortunately, there seems to be no simple experimental test of such recall for the simple and basic reason that one can not observe another person's sensory experiences.

Acknowledgment

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References

Desor, J. A., and Beauchamp, G. K., The human capacity to transmit olfactory information, Perception and Psychophysics **16,** 551-6, 1974.

Engen, T., Identification of odors. Amer. Perf. **76,** 43-47, 1961.

Engen, T., and Ross, B. M., Long-term memory of odors with and without verbal descriptions. J. Exper. Psychol. **100,** 221-7, 1973.

Jones, F. N., Information content of olfactory quality, in Theories of Odors and Odor Measurement. N. Tanylac, ed., Robert College Research Center, Bebek, Istanbul, Turkey, 1968.

Lawless, H. T., and Cain, W. S., Recognition memory for odors, Chem. Senses and Flavor **1,** 331-7, 1975.

Lawless, H. T., and Engen, T., Memory, in The Yearbook of Science and Technology. McGraw-Hill, New York, 1977.

Lawless, H. T., and Engen, T. Associations to odors: Interference, mnemonics, and verbal labeling. J. Exper. Psychol. **3,** 52-59, 1977.

Mair, R. G., and Engen, T. Some effects of aphasic lesions on odor perception, Sensory Processes **1,** 33-39, 1976.

Miller, G. A., The magical number seven, plus or minus two: Some limitations on our capacity for processing information, Psychol. Rev. **63,** 81-97, 1956.

Shepard, R. N. Recognition memory for words, sentences, and pictures. J. Verbal Learning and Verbal Behavior **6,** 156-63, 1967.

Wright, R. H., The Science of Smell. Basic Books, Inc. Pub., New York, 1964.