

Recent Developments in the Study of Perception: Taste and Smell

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Throughout this paper we will use the word perception in a broad sense. This means that we will not limit ourselves to a discussion of the way in which our senses function, but that we will try to include other factors like memory, emotion and language that all come into play when we have the common everyday experience of perceiving smells and tastes.

At the same time we will try to limit ourselves to those aspects of perception which, in our opinion, might be relevant to people interested in marketing and product development of foods and fragrances. In doing so, we will also stress the role which sensory analysis, the systematic study of human responses to foods and fragrances, can play to guide the development and improvement of products before they undergo their final market test.

Over the last twenty years our knowledge about the perception of odor and taste and its practical application in the fields of quality control and product development has grown rapidly, but there is still a lack of integration of the data. Before trying to give an overview of recent findings in the field of olfaction and taste, it is necessary to make three general observations about the perceptual process in the chemical senses:

- People differ considerably in their sensitivity and their appreciation of smells and tastes. Sex differences are found frequently in this field.
- Perception of smells and tastes remains unconscious to a large extent. Smells and tastes influence our behavior long before they attract our attention.
- There is a lack of language to describe smell and taste experiences.

All three observations apply to a larger extent to smell than to taste. The latter two have much more serious consequences than the first one, because they limit the validity of a large number of research

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methods which are based on asking people to describe their perceptual experiences. Thus, asking ordinary consumers what they think about the taste of a product or even what is the nature of the difference in smell between two products may lead to highly untrustworthy answers.

The problem is that ordinary consumers cannot answer such questions. They do not normally analyze their experiences consciously and they have no words to describe the multitude of details they can experience when they do so now. If they answer, which unfortunately most people do when asked such a question, it is by rationalizations or by gross generalizations.

Since all of them belong to the same culture their ways of rationalizing and generalizing are much the same. As a result, they tend to give the same answers. This gives the investigator the false impression that they all agree upon the subject matter of the question itself instead of upon their way of answering impossible questions with rationalizations and generalizations.

The marketing literature and—to be honest—much of the scientific psychological literature is full of such artificial and spurious results. Many a product flop in the food industry can be traced back to them.

In describing the progress that has been made in the study of perception, the traditional areas of research and their interconnections will be discussed.

Intensity—Detection threshold

The oldest question asked in the psychology of perception is, "How strong should a stimulus be to be perceived?" Since it was first asked by Fechner in the middle of the nineteenth century, it has become clear that there are a number of factors which influence our detection and that even a simple question like that cannot be answered on the basis of knowledge of the concentration of the physical stimulus alone.

The human senses are not invariable in their sensitivity. They are subject to adaptation (reduced sensitivity after prolonged response to a stimulus) and habituation (reduced attention to monotonous stimulation) and to variations caused by physiological factors such as changes in the blood stream due to vasodilation and vasoconstriction (rapid changes) or changes in hormone levels (slow changes).

But most importantly in the context of this paper, there also has been the realization that the detection of a stimulus depends on a decision process in the observer. When the stimulus is very weak, and the observer is in doubt whether he perceives it or not, his expectations about the occurrence of the stimulus and his motivation to appear a keen observer, or to be seen as a more conservative observer who

wants to know things for sure before answering positively, will greatly influence his response.

Insecure people may have a strong tendency to be extremely conservative in this respect. This means that they may perceive a lot more than they are willing to admit. In our society men and women still differ in this respect, women being slightly more insecure and therefore more conservative.

In practice, one tries to circumvent the influence of subjective decision criteria by using forced choice procedures, in which one tells the subject that there is a difference between two or more samples and asks him or her to indicate where it is or in what direction it goes (A stronger than B or B stronger than A). The subject must answer, even if he or she has a feeling of absolute uncertainty.

In many such cases subjects, who have the feeling they are merely guessing, do far better than would be expected by chance. This means that they perceive more than they believe they perceive.

The consequences of this simple fact are important. It means that ordinary consumers are not the best observers to ask such simple questions as: "Do you smell or taste something?" or "What do you smell or taste?". Consumers are of paramount importance in deciding about the future of a product, because they can indicate what they like and dis-

like, but they should not be used to settle analytical details. Even in a well-trained panel, forced choice methods should be used.

If women are usually somewhat more conservative in their responses, it should be noted on the other hand that, due to hormonal factors, they are in general more sensitive to odors. As Koelega, et al., (1974) have demonstrated, this superiority in sensitivity arises from the hormonal changes that take place at puberty. Before that age no dramatic differences between male and female subjects are found.

At the arrival of puberty, women also start to fluctuate in their sensitivity to odors in relation to their menstrual cycle. During ovulation they are most sensitive, and in the period between ovulation and menses they are least sensitive.

As was pointed out above, the differences in sensitivity between people may be large, and this does not apply to all odorous substances in the same way. Sometimes these differences are extreme, as in the case of specific anosmia, where a part of the population (usually more men than women) cannot smell a substance at all, although the same people have a normal sensitivity to other odorous substances. Well-known examples of such substances are musk odor and the odor of androstenone which have been considered to play an important role in sexual attraction by some authors. Whether this latter claim is true, is doubtful.

Even if such extreme cases as anosmia are not considered, people differ considerably in their sensitivity to different substances. Usually, the correlations between the sensitivities of a group of people for two different substances are in the order of 0.15 to 0.40, which is very low indeed. This finding is important, because it means that chemically complex stimuli like foods and perfumes will almost certainly be perceived differently by different observers, the one being more sensitive to one group of components the other to another group.

Intensity function

Of course the lower end of the intensity range, which has been discussed so far, is not the only aspect that is of importance. The growth of the perceived intensity of stimuli with increasing concentration has also large practical implications.

In general, this growth of the perceived intensity (S) with concentration (I) is described by Stevens power law ($S=I^n$) which can graphically be represented with a straight line in a double logarithmic plot in which n will determine the slope of the line. In Figure 1, two of such lines have been drawn for two different hypothetical substances A and B. As can be seen these two lines differ considerably in slope and even cross each other at a given point.

This has the following important consequences:

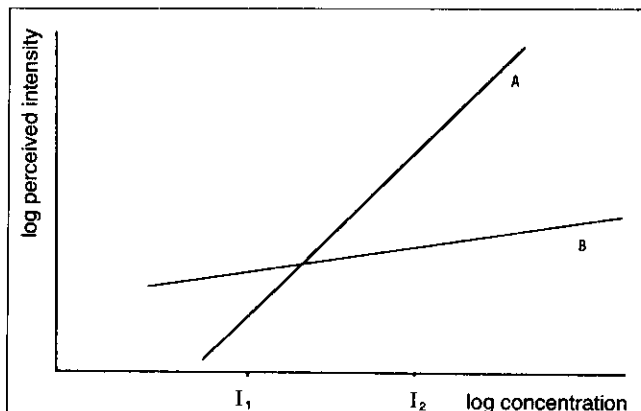


Figure 1. Schematic rendering of perceived intensities of two different odors at concentrations I_1 and I_2 .

- Above point P substance A appears to be the stronger of the two; below point P, component B will be stronger.
- With increasing concentrations the strength of substance A will rise rapidly, whereas the strength of B rises only slightly.

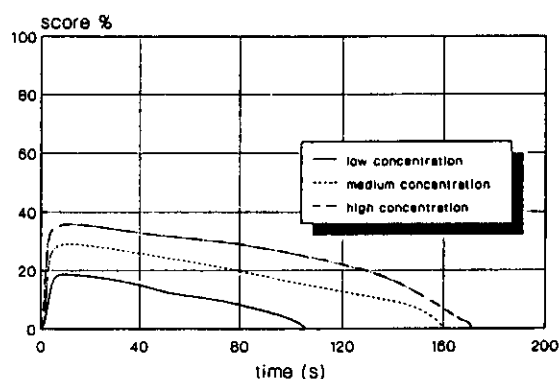
Now consider the following example. Let A and B both be components of a butter flavor added to margarine. In a first test, concentration I_1 is added to the margarine. The observers find an excellent butter taste, but consider it too weak. As a consequence in the next test a higher concentration I_2 is added. Now the observers find the flavor to be much stronger but the enchantment of the butter flavor is gone, because component A dominates.

This is an illustration of the difficulties the product developer is faced with. In such a case, careful laboratory studies using good sensory techniques should be carried out before embarking upon expensive consumer testing.

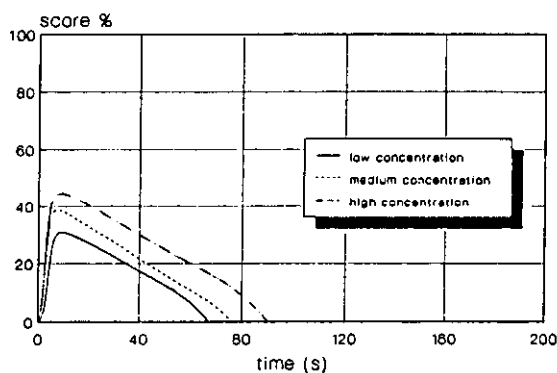
Insight into the intensity functions of odorous substances may also help the product developer in an early stage. If a perfumer wants to develop a perfume he will be interested more in type B substances than in type A substances, because substances with a low slope have the advantage of already being perceptible at a large distance without becoming overwhelmingly powerful in the nearness of the person wearing the perfume. This is especially important, since we know that all pleasant odors tend to become unpleasant at high concentrations.

Time-intensity measurements

Quite recently, there has been an upsurge of the interest in the study of the growth and decay of the intensity of olfactory stimuli over time. How long does it take a stimulus to reach its maximal intensity? Does it decay rapidly or slowly under the influence of adaptation? Does concentration change these parameters?



a. Subject 2.



b. Subject 3.

Figure 2. Examples of time-intensity functions obtained for geraniol at three concentrations by two different observers.

Such questions, which are of importance because the time-intensity functions of different components of such a complex mixture as a food or a fragrance may determine the sequence in which we perceive different aspects of the product, have for a long time been difficult to answer. Since the computer revolution they have become within reach.

Figure 2 gives an impression of the time-intensity relationship for three different concentrations of the same substance by two different observers. They were recorded in our laboratory by De Wijk in a joint project with Dr. Overbosch of Unilever Research Laboratory.

As can be seen from the figures, the two subjects produce very dissimilar curves when they are asked to continuously register the perceived intensity from the moment they start smelling until the moment when the smell has disappeared as a result of adaptation. One of the problems with the method of time-intensity functions is that one does not know whether such differences reflect time differences in perception or are merely the results of differences in response behavior. Nevertheless, one can obtain valuable information from this method, provided

one compares the results of the same individuals for different substances. However, the method is not yet suited to tackle the very complex temporal problems that are involved in eating a food.

Sensory Quality

With the term sensory quality we indicate the type of odor or taste we perceive. In this sense the term has no evaluative connotations and it should not be confused with product quality as used in market research. Whereas the sense of taste can only distinguish four basic sensory quantities (sweet, sour, salty and bitter) or perhaps five (metallic) or six (umami according to the Japanese), the sense of smell is able to distinguish a great many different smells. Even such very similar molecules as the enantiomers of (for instance) carvone, which do not differ in structure but are just mirror images of each other, can be discriminated by smelling them.

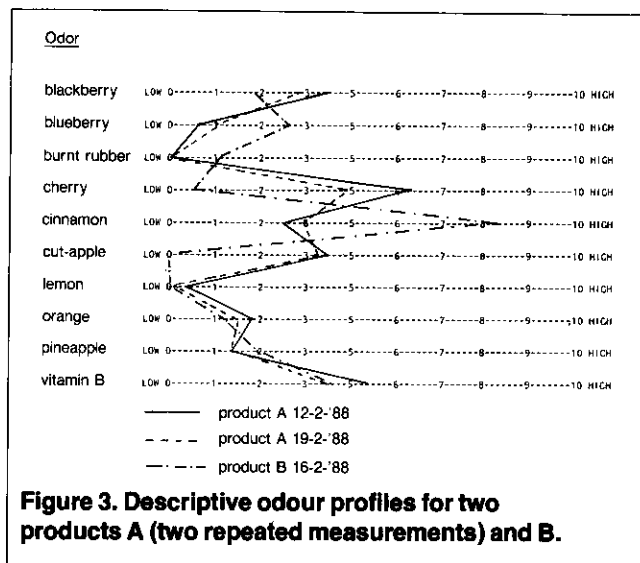
In a chemically complex mixture like coffee or perfume a large number of different odorous substances may be present which each contribute to the final "taste" or smell, and minute differences in composition may lead to considerable differences in their overall acceptance. Although the nose can easily discriminate between odorous substances, it is almost impossible for untrained people to describe the nature of the difference, as was pointed out above.

In product development and product renovation this is a great handicap, because there it is essential to translate consumer preferences into manageable product properties. In other words, one has to know *what* are the underlying perceptible properties of the product that determine the evaluative judgements of the consumers and one cannot ask the consumers directly about this.

In our view the only good solution to this problem is to make a radical decision and to use consumers only for making hedonic judgements, i.e. to tell us what they like and do not like, but never to ask them to describe what they do like or dislike about the smell or flavor of a product. These questions should be put to specially trained people who will be able to make very precise product profiles for the products that are liked and disliked by the consumers.

Comparing the profiles for these products will then show what are the important factors in the decision of the consumer, provided the descriptive panelists have done their work well and have described the perceptible properties of the product exhaustively. In order to be able to do so, they need to be very well selected observers and they need to be thoroughly trained in the description of this type of product.

This is the basic approach which underlies the "Quantitative Descriptive Analysis". In setting up a



descriptive panel for this method, we select the ten best people out of a group of a hundred by a battery of tests measuring their normal odor and taste sensitivity, their memory for odors, their capability of making and remembering odor classifications and, last but not least, their verbal creativity. We also interview these people about their willingness to stay in the panel for a long period (four years) and we estimate their possibilities of becoming a good and cooperative member of the panel.

After this, they receive an extensive training with the type of product on which they are going to work. In about 25 to 30 two-hour sessions they will work with as varied a selection of the type of product as possible and they will develop a common language to describe all sensory aspects of this product in a profile. They will be trained to use descriptive terms only and to omit all evaluative connotations, because as much as we want the consumers to remain consumers and just to tell us what they like and dislike, so do we want our trained panel to merely describe the properties.

After training, the descriptive panel can be used to make detailed and exhaustive profile descriptions of the visual and tactile aspects of the product and of its smell, taste, mouthfeel and aftertaste. Figure 3 gives an example of a set of odor descriptors used by a panel, given two identical samples (A) at two different sessions, and one different sample (B). As can be seen, the profiles of the two identical samples are very close together except for one descriptor (Cherry) whereas the profile of the other sample was quite different on a number of descriptors (cinnamon for instance).

Some of the terms (cut-apple and Vitamin B for instance) may seem very strange. In fact, the panel members have found these descriptors to be characteristic for some samples in the set they were

trained on. Vitamin B odor was the odor that one of the panel members knew from a Vitamin B product she regularly used. When she first mentioned it, none of the other panel members knew what odor she meant. So in the next training session she brought the Vitamin B product along and everybody agreed that exactly such an odor was present in some samples of the product under study and not in other samples. This was subsequently tested by a blind test in which products with and without the odor had to be tasted.

Later, it could be shown that it was this odor and the odor of cut-apples that proved to be very important in the like-dislike decisions of consumers of the product. Samples with and without these odors were further analyzed with instrumental methods and it could be shown that the Vitamin B odor was due to a substance formed when the product was slightly overheated during processing. This is a clear example of finding something that would never have been found by asking ordinary consumers to describe the product.

In our experience, such examples are the rule rather than the exception, because obvious off-flavors in a product have usually been weeded out long before the product reaches the consumer. Only the small off-flavors that cause small irritation in the consumer are overlooked. Such small irritations may nevertheless be very important and may kill a product, as we will see when we discuss the dynamics of preferences and aversions in the section about pleasantness below.

The method described here is certainly the best, but also the most expensive. Many attempts have been made to shorten the method, but most of them have very serious drawbacks.

The best way of cutting costs is perhaps to use a descriptive panel as described here for more than one type of product, retraining them whenever the need is there. Once trained on one type of product they have learned how to find words for their experiences. Thus, one can reduce the number of retraining sessions considerably (± 10 sessions are needed still). By using the same panel again, one also avoids the cost involved in the selection procedure.

Other procedures, like the much-advertised free choice profiling, have serious drawbacks because they rely on less well selected and trained people. The idea of free choice profiling is not to insist on the development of a common language for all panel members, but to let each individual use his own set of descriptors and to relate the different sets of descriptors of different observers for the same products by complex statistical techniques.

Although some people already object to some of the statistical transformations used, the main draw-

back of the method is in the fact that without proper training precisely the small off-flavors that very often prove to be so important are overlooked. As said before, the problem is not to find the obvious defects but to look for the unobtrusive ones. And since people are not built to look for the inconspicuous, they have to be trained to do so.

Still another approach is to let "experts" formulate the descriptive terms and then to ask a panel of observers to profile these terms after some form of training. A number of objections can be made. First of all, "experts" do often overrate the importance of certain aspects of the product, whereas they underestimate the importance of other aspects. Also their lists contain very often a mixture of evaluative, descriptive and technical terms (good coffee taste, papery taste and aldehydic taste).

By the very fact that they have become experts, they have lost touch with the frame of reference of the consumer. This does not mean that experts are not important. They are indispensable for the evaluation of technical details of the product, but they can not be used to predict consumer preferences.

Furthermore, the panel members who have to use the terms will often differ in their interpretation of them. This is particularly true of the technical terms. Even with a lot of training, they may still have different interpretations of a word handed down to them and not created by them in general consensus.

Also, the list of terms will usually be too short to fully and exhaustively describe their experiences. This means that they will attach certain experiences to certain of the provided terms instead of creating a new one for them. Since it is likely that different people make these attachments in different ways, a lot of noise can be introduced in the data.

In conclusion, we prefer the quantitative descriptive analysis approach above the others, because it is the best way to avoid errors and although the cost of the method is high, it is slight compared to that of a product flop. Used along with an indicative consumer panel, consisting of about 60 product consumers, the descriptive panel can be used very effectively to improve or develop products, following the procedure given schematically in Figure 4.

Starting with a number of versions of a product, given both to the descriptive panel for profiling and to the indicative consumer panel for hedonic (like-dislike) judgement, one can compare the profiles of the liked and the disliked versions and find out what sensory qualities are responsible for the differences.

One can then develop a set of improved versions. These versions may again be described by the descriptive panel and judged on pleasantness by the consumer panel. Usually, after two or three of such

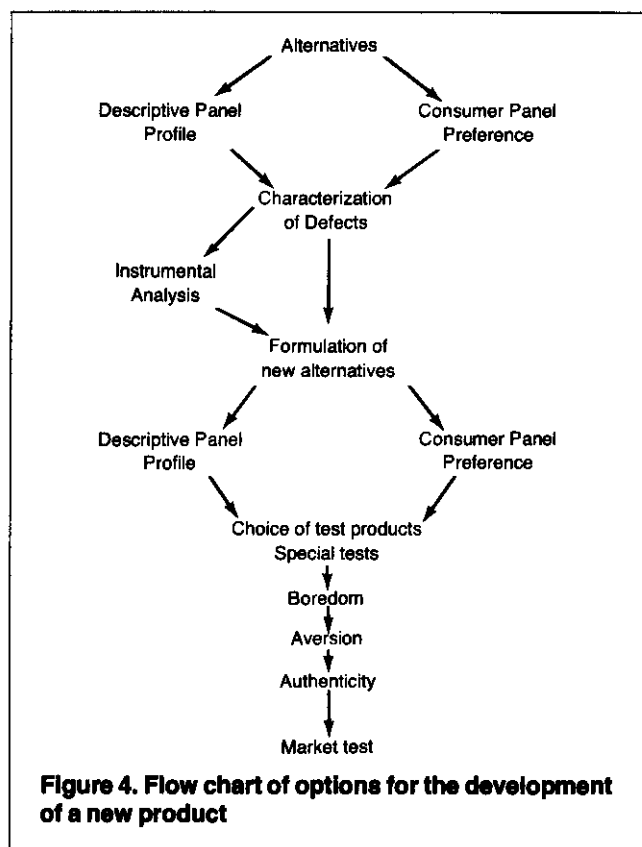


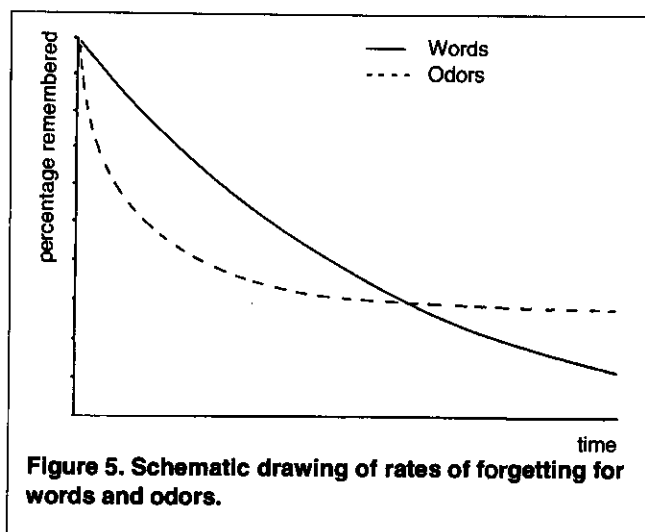
Figure 4. Flow chart of options for the development of a new product

rounds, the final product versions, for further testing with special panels (see below) and large consumer panels, can be selected. Depending on the problems of creating improved versions, such a procedure can be completed in 4 to 6 months, provided a trained descriptive panel is available.

Role of memory

Before leaving "quality" as a subject, some general remarks should be made about the role of memory. Although we have great difficulties in describing the quality of smells and tastes, our memory for them can be very precise. We may experience a particular smell or taste and all of a sudden we may know that this is exactly like the odor we experienced in the garden of our grandparents at the age of seven or that this taste is precisely the taste of a cake we ate before the war when we went to a certain place for morning coffee. What is typical about these experiences is that the sensation carries us back to a situation rather than to the source of the odor or taste itself.

Memory for odors is different from our memory for words. Even though the percentage of odors remembered drops more drastically at the beginning, it is also clear from Figure 5 that the odors we retain will remain with us almost forever. This means that we have a set of very precise notions of how a product should taste. It is therefore very dangerous to



change a product without indicating to the consumer that it has been changed, unless the change is so gradual that it is never perceived.

Such cases are known. An example is the very gradual change introduced in the taste of rum for instance. Although such a change is apparently successful, it always carries the risk that the consumer will find another brand that is more identical to his memory and becomes disloyal to his (changed) brand.

Another example of this may be found in the present wave of 'light' versions of food products. Sometimes such versions try to mimic the original full product, but they will only partly succeed in doing so. This means that they carry the built-in risk of being abandoned. In our opinion it is better to create clearly different "light" products and to bring them as such to the market, unless one can really make a perfect match with the old product.

Pleasantness

The last part of the foregoing section has already led up to the introduction of this last, but in context perhaps most important, aspect of odor and taste perception: pleasantness. There is still some discussion about the question whether our hedonic judgement about odors and tastes precedes our perception of them or not.

In a way this is a false discussion, because we already know that we may react to odors and tastes without consciously perceiving them. It is certainly true that odors and tastes are almost always accompanied by immediate emotional reactions. At birth we come into this world with a dislike for bitter and a like for sweet.

This does not mean that our preferences are fixed for life. On the contrary, we may learn to like the bitterness of beer and even of campari and we may later in life learn to dislike the sweetness of certain products.

In this development of our preferences there are two periods in life that are extremely important: the period up to eight years and the period at the end of puberty, when we start to make our own decisions.

The most stable preferences are formed in childhood, for those products that we first learn to eat at home and of which we are allowed to consume only limited quantities, or with which initiation rites are connected (chocolate, ice cream, cola).

Beer is a good example of the latter category. We may take a sip of our father's glass, swallow the horrid stuff and shout "nice" or "wonderful" to convince mainly ourselves that we have now entered the world of the grown-ups.

Stable preferences are also found when we decide on our own private lifestyle and settle down with another person during adolescence.

Although such stable preferences play an important role, many of our preferences for new products are formed in later life. What are the factors that determine such preferences? There is still a lot of discussion around this question and it would be unproductive to reproduce all the details of this discussion here. Factors like neophobia and perceived stimulus complexity are mentioned, but it is too

early to decide on their effects in a final statement.

The only thing that is clear is that men and women differ considerably in their preferences for foods and fragrances. In a number of experiments we were able to demonstrate that men have much simpler tastes than women, and that women can exchange the pleasure they get from eating much for the pleasure of eating something varied and refined, whereas men can not.

This is not new, but it has implications for the development and marketing of foods. Thus, providing variety will help women to eat less, but will not influence the eating behavior of men very much.

Another important aspect of pleasantness is its durability. Product boredom will develop for almost all products that are eaten regularly, but for some products it will develop much more rapidly than for others. At the moment we are developing methods to predict such consumer boredom. They consist of special tests that we carry out with groups of consumers. They are mentioned in Figure 4 and play an important role in the final stages of product development.

Unpleasantness

Normally one would consider unpleasantness to be the opposite of pleasantness, but this will often lead to very false conclusions, because many products that are judged on the whole to be pleasant may have some unpleasant points. The problem with such products is that over time the pleasantness will wear off (product boredom) but the irritation over the unpleasant aspects will grow rapidly.

Negative aspects of the perception of a product are very often underestimated in market research. Nevertheless they are usually more important than the positive ones. If my wife buys a new perfume which in general I like, but there is a small note in it which I dislike, the chances are very great that in the long run I will ask her not to use it, because this one little note is irritating me more and more.

In the case of a perfume this may already be bad for the product, but if more frequently used consumer goods like a soap are concerned, the effect may be deleterious. If one out of every four people has the same experience as me, that product may be killed.

In order to test this in an early stage, we devote much attention to negative aspects of the product and we carry out specially devised "aversion" tests with panels of consumers, which can predict whether such aversions will develop. These tests have now been validated with a number of products in experiments in which products were compared that had been put into the market with the same marketing strategy, same distribution, advertising etc. and of which the market success is already known.

These products were provided to us under "double blind" conditions and we made "a posteriori" predictions of their market success on the basis of a series of short tests. The results obtained so far are very convincing.

Like preferences, aversions are often created in early childhood by parents who promise something nice if their child first eats something else (Lipps Birch, et al., 1984). They may also be the results of negative feelings directly following the eating of a food, even if they are not connected with the food in any direct way.

The problem with aversions is their persistence, because the people who have them tend to avoid the things they dislike and thus never learn to overcome their aversion.

Before concluding the section on pleasantness and unpleasantness, it is once more useful to point out the role of memory. Since our memory for odors and tastes is so precise and since almost all odor and taste experiences are accompanied by emotions, odors and tastes can very easily evoke accompanying moods. Unfortunately, these moods are very much linked to the personal history of the person who perceives the smell or taste.

This is one of the reasons why it is so difficult to find a common denominator in peoples' reactions to tastes and smells. In the fragrance industry, it has become fashionable to search for mood fragrances. Although perhaps no other sensory stimulation does influence our mood more than odor, it is very difficult to find general effects, unless the odors remind us of very general experiences which we all have shared and which have either a biological (sex odor) or a very broad cultural (odor of Christmas trees?) basis.

Concluding remarks

In this paper we have tried to give an overview of the present knowledge about olfactory and gustatory perception from a viewpoint that leaves room for practical application of the knowledge. Smells and tastes are often perceived unconsciously by consumers. They evoke personal memories and moods, but can hardly be described adequately, unless specific training is given.

In the perspective of market research it is better to use consumers only for making direct hedonic judgements and to use highly trained panels for the translation of consumer likes and dislikes into tangible product properties.

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