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CRITICAL EVALUATION OF SENSORY TECHNIQUES

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ABSTRACT

Key methodological issues in sensory evaluation are discussed: the selection of subjects, the types of stimuli, the environments for testing, and the actual methods. Concerning subjects, we need to sample more broadly, consider both individual and subgroup differences, and consider cognitive and cultural factors. The stimuli in sensory evaluation need to be sufficiently complex to permit analysis of realistic complex foods and even meals. Sensory evaluation must look beyond the laboratory to study other environments and the factors within them that control product acceptance. Choice of sensory method should be based on better methodological data on how methods perform and at what cost in resources. There is a need for more methodological research to establish the reliability and validity of sensory methods. Also, there is a need for integration of sensory and hedonic dimensions rather than separation of these dimensions.

Keywords: Sensory evaluation; testing; methodology; stimuli; validity; hedonic.

INTRODUCTION

I am very pleased to have this opportunity to comment further on methodology in studies relating to human food habits (see also Meiselman, 1992*a*). As a person trained in basic sensory psychology and physiology, I have attempted to bridge the gaps between sensory science (how do taste, smell and other senses function), food habits (how do taste, smell and other senses influence eating), and product evaluation (how are taste, smell and other senses related to product acceptance?). I believe that I am in a tradition in which Professor Pangborn was a pioneer and steady contributor. I have become more and more concerned about what Lawless (1991) calls 'The rocky road—connecting basic research to practice' (p. 7). Lawless states the unthinkable and 'uncomfortable notion that taste perception simply has a weak influence on food habits', and further that 'individual food habits are determined by so many diverse factors that a relationship to individual taste sensitivities is easily obscured' (p. 10). I reached a similar conclusion about the status of sensory factors in food habits and recommended that human eating research refocus on different variables and different methods (Meiselman, 1992*a*).

These underlying questions of sensory relevance can be tied to another fundamental issue in our field, the sensory-affective dichotomy. Traditionally, we have recommended different 'sensory methods' for analytical work versus hedonic or affective work (Institute of Food Technologists, 1981). The former tend to utilize trained panels and the latter, consumers. In the former, we assume that the food is being studied; in the latter, we are studying both the food and the consumers. Sensory specialists utilizing sensory evaluation techniques can adequately describe the sensory characteristics of products. However, when we try to predict consumer acceptance or usage (acceptance or consumption for foods), we have more problems (Pangborn, 1979; Koster, 1981; Lawless, 1991; Meiselman, 1992*b*).

Lawless and Klein (1989) have tried to distinguish sensory evaluation in academic and industrial settings. Although they note that 'the methodology ... defines this area as field' (p. 206), they further point out that method is not the paramount concern in academia or industry. In the latter, the main interest is the product; in the former, the interests are other concepts and variables not necessarily related to a product. And the potential to address sensory methods is affected by the relative lack of advanced training in sensory analysis/sensory evaluation (Pangborn, 1987; Lawless & Klein, 1989).

I will return to some of these issues at the conclusion of my paper. But let me get more specific about sensory methods. I will discuss sensory methods and their context as follows: the test subjects, the test stimuli or foods, the test environment, and the methods themselves.

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SUBJECTS

Sensory evaluation has maintained a simplistic approach to choice of subjects or panelists. In many situations, participation is based on availability. Traditionally, it is recommended that panelists be screened for basic sensory capacities.

In contrast to sensory evaluation, market research has focused heavily on subject demographics and market segmentation. Marketing segmentation is based on standard demographics such as geographic locale, socioeconomic status, gender, ethnic group, age, and race, as well as criteria such as values, beliefs, and lifestyle. Most marketing questions would be viewed as meaningless if applied to the entire population.

In sensory evaluation there are only a few published examples of consideration of panelist demographics and segmentation panels based on personal characteristics (e.g. Tuorila-Ollikainen & Mahlamaki-Kultanen, 1985; Tuorila, 1987). For some health issues, sensory evaluation has compared responses of people with anorexia, for example, to a control sample (Drewnowski, 1989). But within the very broad range of healthy people there has been very little attempt to segment sensory panelists. One exception to this is Moskowitz (1983), who has tried to bridge the gap between sensory and market research.

However, Cardello (1992) is presenting considerable data that a subject's expectations can affect his/her impression of a product. Cardello has sought to determine whether products moved towards our prior expectation (assimilation) or further away from our prior expectation (contrast). As expectations and other cognitive determinants (see appropriateness below) are seen as major factors in both sensory and hedonic responses, then we will have to give more consideration to the differing expectations of different subject groups.

The sensory evaluation field continues to distinguish between consumer panels and trained or expert panels. Consumer panels are assumed to be 'people off the street' with no special training or selection factors, although testing is sometimes restricted to product users. Trained or expert panels are assumed to be selected on criteria and further trained either deliberately or through experience.

Given that consumer panels are supposed to represent 'people off the street' do we really utilize a broad range of subjects in consumer sensory studies? Probably not. Most studies have a narrow range of ages, socioeconomics, racial and geographic factors. Many consumer panels are really convenience panels rather than panels representative of the consumer, and we do not know the effects of our panelist selection decisions. Further, much of the knowledge is proprietary and not available to the broader scientific community.

The use of trained panels is an important part of sensory tradition. Although expert tasters and smellers go back hundreds of years, the notion of formal selection and training of sensory panelists appears to have its modern roots with the flavor profile method (Cairncross & Sjostrom, 1950). Not enough published research has compared consumer panels and trained panels, so we do not know precisely how they differ in performance, if indeed they do. I know the purist will say that consumer panels and trained panels should have different objectives and different tasks, but it is still worthwhile to know whether there is a performance basis for the distinctions usually drawn between the two. Further, what constitutes a trained or expert panel is itself unclear. Lawless (1984) has distinguished panels which receive special training, panelists based on long experience, and panelists based on special sensory abilities. The proponents of trained panels have directed numerous groups to invest in training and maintaining panels, but they have not generally published or presented studies on the efficacy of panel training. Published reports and papers need to be more specific on how sensory panelists are trained and on what instructions and orientation they receive.

Much of the need to train panels appears to follow from the desire to get everybody to use the same language and measurement technique. It is clearly a convenience for the experimenter to get a (small) group of people with similar use of methods and words. But does selection and training do more than encourage easily digested communication? We do not know. O'Mahony (1991) and O'Mahony *et al.* (1990) have argued that if sensory concepts are not aligned there can be no meaningful communication about sensory events. This issue will be pursued further under Methods, below.

Professor Pangborn was extremely interested in individual differences among sensory subjects (e.g. see Pangborn, 1981). She argued that the average response often masks important information about the subjects and the product. This is the case both with sensory measures and hedonic measures but can be especially problematic with the latter because hedonic measures can be multimodally distributed.

Since much sensory evaluation is done with small sample sizes, there is usually no statistical basis for determining subgroups. Moskowitz has attempted segmentation with his samples based on demographics, attitudes and lifestyles (Moskowitz, 1983, p. 451). The use of consensus judgment in some methods totally obliterates individual differences. However, the descriptive methods which sometimes use consensus judgments and which use extensive panel member selection and training can be an excellent source of information about individual differences. Such panels often collect detailed individual data to evaluate panelist performance (Powers, 1988). However, the same data could

be used to study individual differences as an independent variable. Stevens (1991) has also recommended further study of individual differences as independent variables, in order to understand sensory phenomena better.

Sensory evaluation needs a more sophisticated approach to subjects in testing. We must broaden the focus on the product to examine the people doing the testing. We need to learn how their different physical characteristics (age, biochemistry, etc.), social characteristics (culture, etc.) and individual characteristics (expectations, etc.) affect sensory responses.

FOODS

I noted two decades ago (Meiselman, 1972) that basic sensory research should use stimuli which are more relevant to real foods. Professor Pangborn was one of the few researchers who attempted to study chemical stimuli in the context of foods. One of her first published studies used peaches (Simone *et al.*, 1956); I worked with her on methodological research using cocoa beverages (Pangborn *et al.*, 1989). In my recent review of human eating research (Meiselman, 1992*a*) I again noted the same issue of using stimuli which were not realistic and which lacked the complexity of foods as eaten.

In our attempts to control experiments on foods, we have continued to utilize chemical stimuli and food stimuli which are extremely simple. For this reason, research on sensory evaluation and human eating does not permit prediction on reactions to real foods by real consumers in real situations. The complexity of individual food dishes, and the complexity of the meals created from them, and the longer-term diets created from those meals are missing in our approach and in our data.

We are still struggling with the basic phenomena of how tastes combine and how smells combine. Pangborn and other participants at the 1986 conference on sweetness expressed the difficulty of understanding how sweet taste interacts with other tastes and other sensations in sweet foods and beverages. Rolls (1987) asked, 'Are real foods too complex for this type of analysis? How can we learn about complex foods?' (p. 65). Rodin (1987) followed up with, 'Why is the literature on taste interactions in actual foods and beverages so sparse and unsophisticated? ... Do the developments need to be methodological or are there conceptual problems that need to be ironed out?' (p. 65). Pangborn (1987) stated that taste interactions generalize from aqueous solutions to foods for discrimination and perceived intensity tasks but not for hedonic responses or intake.

We are faced with a dilemma. Should we subscribe to a model of science in which each variable is studied in isolation in the laboratories, with all other variables held constant? Remember that even at the supposedly simple level many issues are unresolved. How to describe gustatory stimuli and how to profile a range of these tastes is still the subject of intense debate (O'Mahony *et al.*, 1990). Even if simple issues were simple, single variable studies would be followed by studying two or more variables so we could examine interactions. The sensory complexity of meals and diets is so vast that this model is overwhelming, and we would also have to include nonsensory factors. Can we appreciate our reaction to a large master painting by understanding the reaction of the eye to individual pure colors and saturation? The building block approach of basic sensory science will not work for foods.

We need to increase our research on more complex foods and entire meals. There might be quite a bit of this in industry but we need more in the research literature. We need better ways to describe sensory complexity and to describe the interactive effects of meal components.

There has been a thread of research over the past 20 years on how individual foods combine to produce meals (Moskowitz, 1980; Turner & Collison, 1988). I have teamed with colleagues at the Institute of Food Research (UK) and Bournemouth University (UK) to look at this issue again. We need simple metrics to aid the researcher or practitioner to combine meal components to yield an overall meal score for sensory or hedonic measures. The development of such a metric would encourage more focus on overall meals and, hopefully, more attention to inter-item compatibilities.

ENVIRONMENTS

Sensory evaluation has developed as a laboratory-based technology. Earlier texts described minimum or ideal testing conditions for sensory evaluation. Such conditions usually maximized control of sensory phenomena and minimized intrusion of 'other variables'. However, standardization has never reached high levels, and the details of how each laboratory conducts sensory work is not documented.

This variation in methodological control extends to the physical environment and to the social environment. Some investigators use pure chemicals, purified air, controlled atmosphere, special selected laboratory materials (nonodorous, etc.); others use whatever is available to them. Some isolate panelists from other social input, while others permit or even encourage social discourse.

Unfortunately, while sensory evaluation has tolerated a wide range of practice, we have rarely subjected many of the environmental or situational differences to test.

Perhaps we need not be as careful as some of us think; or perhaps we need to be more careful! Of course, much of this depends on the nature of the specific task. We could tailor our approach to the work if we understood better the effects of different environmental variables.

Two broad areas concern me in sensory evaluation history and practice relative to testing environments and situations.

Temporal issues

Sensory evaluation as a technology mirrors its parent discipline of sensory research, which has never adequately dealt with the temporal aspects of human response to chemical stimuli. Sensory psychophysicists and sensory neurophysiologists have both used highly arbitrary temporal limits for sensory events. Neither has related these temporal limits to the temporal parameters of chemical senses functioning in the real world. Halpern and Meiselman (1980) tried to introduce a more dynamic real life simulation into human sensory gustatory psychophysics, but this approach never caught on. Halpern (1991) has elegantly studied the temporal aspects of basic taste psychophysics, but this has generally not been applied to gustatory, let alone to sensory, evaluation.

Similarly, in sensory evaluation there appear to be no empirically based temporal parameters for testing. We need to be able to design studies with databases that provide guidelines for the following questions:

(1) How long should a stimulus last?
(2) How many stimuli per session?
(3) How long an interval between stimuli?
(4) Should questions be asked on the after-effects of stimuli; if so, how long after?

These questions get more complicated with more complex stimuli. For simple chemical compounds like table salt (NaCl) one can find references (O'Mahony, 1979; Halpern & Meiselman, 1980); however, for many compounds, for more complex food dishes, or for meals there are no references.

Another aspect of temporal concern is longer-term effects. I have raised this same issue for human eating research (Meiselman, 1992*a*). With respect to sensory evaluation, should sensory events be tested once, or over a few days, or over a few weeks? If one wants to evaluate desserts, for example, is it sufficient to ask in one session? Might the results change over time? The broader question here involves both the validity and the reliability of sensory and hedonic data. Repeated testing of hedonic data could uncover how to best predict consumer behavior such as purchase or consumption. Such testing could also uncover the inherent variability in some of the phenomena in which we are interested.

Laboratory environment

As I noted above, sensory evaluation is a laboratory-based technology. However, in the field of human eating research we have noted the great effects that situation has on results (Hirsch & Kramer, 1993). In fact, situational variables, to include the physical and social environment, probably control food intake more than sensory. In my opinion, one of the great failures of sensory-oriented food habits research is to demonstrate the importance of, and priority of, sensory variables. I no longer take it as a given that sensory factors are important in controlling daily food habits.

Does sensory evaluation properly consider testing environment? We do not have a good appreciation of the places in which sensory evaluation is carried out because much of the work is proprietary. But it can be safely assumed that very little of the work is carried out where people normally eat. The suitability of our techniques to be used in a variety of situations is another untapped area. Lawless and Malone (1986*a*,*b*) reported the ease of using different scaling techniques which allow some generalization to different testing environments. But there has been very little testing and reporting of sensory methods in different nonlaboratory environments. What sensory methods are best suited to shopping mall studies, cafeterias, restaurants, etc.? Koster (1981) has proposed that more sensory evaluation be conducted in a 'natural' environment. Koster argues that laboratory research imposes limitations related to human contact, naïve behavior, normal use of the product, stimulus context, and response possibility. Some would argue that these are not limitations of laboratory research, but advantages of laboratory research.

Schutz (1988) has proposed a 'sensory scale' to measure the situational effect of different products. He has called the scale appropriateness, and subjects are asked to rate how appropriate a product is for different specific situations. This allows one to quantify whether a product is more appropriate for lunch or dinner, home or restaurant, etc. Appropriateness scaling permits an investigator to ask in a different format than traditional hedonic or sensory scaling and to investigate the impact of a variety of environmental factors. The concept and appropriateness measurement scales have not been widely utilized and reported.

METHODS

To a large degree, an evaluation of sensory analysis should be based on an assessment of its methods. From a strict and traditional perspective, I should try to assess the validity and reliability of the various sensory methods. Assessment of validity, i.e. does a test do what it is intended to do, leads one to examine the different purposes for which sensory tests have been developed.

The different types of sensory tests and their possible applications were reviewed in my chapter in Piggott's book, *Sensory Analysis of Foods* (Meiselman, 1988; p. 306). I listed 11 different applications for sensory evaluation. One complication of examining the validity of sensory tests is this range of possible uses. Tests might be valid for one use but not for another.

Unfortunately, there have been very few published studies on the validity and reliability of sensory methods. Interestingly, there is a great deal of material published on statistical analysis of sensory data (Gacula & Singh, 1984; O'Mahony, 1986; MacFie, 1987; Powers, 1988). We know how to analyze data but we are not sure what data to collect or how to collect it! If there is one outcome of my talk, I hope it is to stimulate more published research on sensory methods. Most sensory evaluation work has had a practical orientation, and there is a lack of real theory. The lack of theoretical issues and competing theories and hypotheses has limited the growth of basic methodological studies.

There has been a commercial and industrial atmosphere within this practical orientation. Many of the sensory methods, other than the early discrimination tasks which were adapted from psychophysics, were developed by academics/consultants or industrial sensory scientists who sold their methods. The developers and proponents of each method wrote (noncritical) articles on the method. The consultant was selling a method, not describing a method, and certainly not evaluating a method. And frankly, the rest of us did not pick up the challenge and investigate these methods. Beginning with the Arthur D. Little Flavor Profile in the 1940s, one could develop and use a sensory evaluation method without much intrusion from the scientific community. Not only has there been very little methodological research, there has been very little methodological development and evaluation because 'quite naturally the originators of a particular method often feel that their method should remain inviolate, that any change detracts from its validity or effectiveness' (Powers, 1988; p. 212).

Last year I had the opportunity to work on this issue with Professor Howard Schutz of Davis, Dr Hal MacFie of The Institute of Food Research, Reading, and Dr David Thompson. We set out to review all of the sensory methods on a standard set of criteria. I developed a set of test criteria, using as my model the criteria which had been developed by test developers (see Anastasi, 1988). The format (Table 1), I believe, has great utility and value to our field of sensory evaluation. The evaluation begins with Part A—General information on the test title, the original reference, and the best reference. Part B describes the purpose, populations and content of each test. Part C covers in detail the practical considerations in tests. Part D, which was our main interest, covers the technical testing considerations of reliability, validity, drawing inferences and sensitivity. Part E optimistically calls for a summary evaluation. I plan to begin filling in these tables for each method with the help of experts.

TABLE 1. Proposed Evaluation Criteria

A. General information
   (1) Title of test (alternative titles)
   (2) Author(s) (original source, key sources)—best reference

B. Purpose and nature of test
   (1) Problems aimed at
   (2) Populations aimed at
   (3) (Subject matter, content)

C. Practical considerations in test use
   (1) Design of test
   (2) Availability of test
   (3) Ease of use/clarity
   (4) Time required
      (a) Training (experimenter and subjects)
      (b) Data collection
      (c) Data analysis
   (5) Data processing
      (a) Data collection
      (b) Data analysis
      (c) Data reporting
      (d) Ease of analysis
   (6) Qualifications required
      (a) Staff (see C(4)(a))
      (b) Subjects (see B(2))
   (7) Costs
      (a) Materials
      (b) Time
      (c) Staff
      (d) Data handling

D. Technical testing considerations
   (1) Reliability
      (a) Types and procedures
      (b) Scorer reliability
      (c) Long-term stability
   (2) Validity
      (a) Types and procedures
         (i) Content
         (ii) Criterion
         (iii) Construct
      (b) People samples
      (c) Food samples
   (3) Drawing inferences from data
      (a) Normative data
   (4) Sensitivity

E. Summary evaluation

Several general issues can be raised concerning sensory evaluation methods. Selection of terms is a general problem for sensory methods. One can identify thousands of words from the dictionary for the subtle differences in the sensory properties of foods, including their taste, smell, texture, and temperature. Some methods specifically deal with this issue of semantics. However, in general, the evaluation practitioner is met with this problem every time he works with a new product. Specific language has been developed for a

number of products (see Pangborn, 1981, p. 21; Powers, 1988, p. 207). But what do we do with a variation on one of these products? Can ripe tomatoes and unripe tomatoes be evaluated with the same terms? What about hamburger versus hamburger in a bun? with ketchup? If one knows the sensory language for hamburger alone, bun alone, and ketchup alone can one add up the terms for a complete set? Are some missing? Dravnieks (1985) has reported one attempt to produce more generalized terms. And others have moved towards free choice profiling to avoid the need for a descriptive language for each product (Williams *et al.*, 1984). The problem becomes even worse when we get into more affective terms (appetizing, healthful, fresh, etc.) or into more complex terms (subtle, unblended, etc.). Do we need a dictionary of sensory terms which can form the basis of more important basic and applied sensory work, or do we need approaches which are less language-based? O'Mahony (1991) has argued why descriptive terms are needed, but I do not understand how to develop descriptive terms for every product, every variation of product, and every combination of product. And further, I assume all those descriptors would not easily translate from language to language.

The discussion of sensory and affective language reminds us that there is still that dichotomy in food testing (see Institute of Food Technologists, 1981). We like to tell our students or customers simple truths such as 'Use sensory methods with expert panels and affective methods with consumer panels'. But the real consumer does not, I believe, differentiate sensory and affective impressions on a regular basis. We need to understand the integration of sensory and hedonic responses and to describe quantitatively the relationship of sensory and hedonic. Treating them as separate does underscore the point that we taste and smell and see and feel with sensory receptors, whereas we have affective responses in our brains. This has been helpful to those lay people who ask how food tastes when they mean to ask if one likes it. But we need to address how sensory and hedonic work together to bring about consumer behavior.

CONCLUSION AND RECOMMENDATIONS

What is the overall status of sensory evaluation today? Are we a 'collection of technical methodologies' as Lawless (1991) suggests, or are we more ... or less? If one's goal is to analyze sensory descriptors of foods or other products, then sensory evaluation certainly can display an array of potential methods. But these methods are still in the stage of development and, in many cases, need more development to reach maturity.

If one's goal is to relate sensory characteristics to product acceptance and product usage, then we are not a collection of methods. We have yet to produce a method, or more likely a combination of methods, which will relate sensory properties of products to human response in the real world and to relate sensory properties of products to nonsensory properties which also contribute to product acceptance.

In order to address these problems, a number of steps must be taken, steps recognized by Professor Pangborn.

(1) First, we must train more sensory scientists in programs such as described by Dr Lawless at this meeting, because

> 'The immediate future promises a continued shortage of sorely needed sensory professionals.' (Pangborn, 1989; p. 252.)

(2) Second, we must conduct and publish more methodological research in order for sensory analysis to take its place in the world of science.

> 'A need for a more critical, more scientific approach to sensory testing ...' (Pangborn, 1979; pp. 2–12.)

(3) Third, we need a greater sharing between academia and industry and a greater dissemination of data.

> 'Generally there is poor communication between sensory laboratories, especially between industrial and nonprofit research groups. It should be possible to exchange information on methods without jeopardizing confidential data on the commodity.' (Pangborn, 1964; p. 66.)

(4) Fourth, and perhaps most important, we need to move sensory analysis from its relatively narrow role in product development to a broader role in developing a perspective of how the senses play in integrated human behavior such as eating.

> 'Sensory science remains an underdeveloped field ... replete with unresolved problems, seeking the expertise of multidisciplinary research teams.' (Pangborn, 1984; p. 76.)

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