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A personal history of sensory science

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ABSTRACT

This article traces the history of Sensory Science in America. It starts with the roots of psychophysics in nineteenth-century Germany, following from Weber to Fechner to Wundt to Titchener to Boring and finally to SS Stevens. Next it discusses early discrimination testing at Carlsberg Brewery in Denmark and at Seagram Corporation in the USA. A brief history of the start of hedonic testing at the Chicago Quartermaster's store by David Peryam will be followed by the start of descriptive testing. Specifically, the work by Jean Caul, Herbert Stone, and Joel Sidel, as well as Elaine Skinner and Gail Civille, is covered. Lastly the seminal effect of Rose Marie Pangborn, and especially her Sensory Evaluation of Food Course on sensory science worldwide, is discussed.

KEYWORDS

Sensory science; Rose Marie Pangborn; University of California, Davis

Introduction

Sensory science can seem counterintuitive to a layperson: it is a field in which comparative judgments can become laws, and individual preferences for one canned apricot over another are expressed mathematically. It is an accounting for taste. The history of sensory science is partly the story of what happens when engineering and physics collide with psychology, and of when relatively old tools for measuring stimuli are coupled with new tools for measuring perceptions of texture, flavor, and odor. Concretely, sensory science involves the harnessing of psychophysics and psychometrics, discrimination testing, consumer sensory testing, descriptive analysis, and statistics to evaluate human beings' sensory experiences. The often surprising history of sensory science unfolds across the United States and Europe in classrooms and laboratories, in breweries and on factory floors, in military mess halls, and even over my kitchen sink, where my dislike of washing dishes led to an unexpected career.

Sensory science was defined by the Institute for Food Technologists (IFT) as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Anonymous 1975). As a research field, sensory science in its current incarnation is about eighty years old and, to quote Elaine Skinner (1989), "Sensory evaluation is a child of industry. It was spawned in the late 40's by the rapid growth of the consumer product companies, mainly food companies." Why is sensory science important in today's world?

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Any food and consumer product—possibly excepting fresh vegetables and fruit—has seen a sensory scientist on its way to market. The field is used in industry for new product development, product reformulation, to keep abreast with the product changes of competitors, and also as a way to position products in the market—this last activity is usually done in conjunction with marketing.

This history of sensory science is written by a California-centric non-historian and should be read with this fact in mind. I am a Distinguished Professor of Sensory Science and the Ray Rossi Chair of Viticulture and Enology at the University of California, Davis (UCD). With Harry Lawless—Emeritus Professor of Food Science at Cornell University, Ithaca, NY—I wrote the currently most prescribed sensory textbook in the world: *Sensory Evaluation of Food, Principles and Practices* (2010). I have had the opportunity to watch sensory science coalesce and emerge as a professional and academic discipline.

In January 1980, as I was finishing an MS degree at UCD with the intent to return to South Africa to become a winemaker, my roommate, Laura Calfee, convinced me to take a Food Science and Technology (FST) course with her. I had no need for this course—FST 107 "Sensory Evaluation of Foods," taught by Rose Marie Pangborn—and had heard that it was a lot of work. However, I agreed if in return she would agree to do the dishes for the duration of the ten-week quarter. Sometimes, life-changing events happen without planning: my aversion to doing the dishes changed my life. About three weeks into the class I was taking notes when it struck me that *this* was what I wanted to do with my life. I wanted to teach and do research in the field of sensory science and, thirty-nine years later, I am still as passionate about teaching in this field as I was on that day.

In this manuscript I delineate how a series of disparate sensory ideas and techniques, from a broad range of characters in very separate academic and industrial fields, essentially coalesced into sensory science, and my thesis is that the major driving force for this was Rose Marie Pangborn through her teaching of the seminal sensory course Food Science and Technology (FST) 107, as well as through her research and personal outreach to scientists and practitioners across the world. Specifically, Pangborn's integration of the disparate concepts such as psychophysics, discrimination testing, consumer testing, and descriptive analysis into her FST 107 course led to sensory science as it is taught and practiced today.

I trace the beginnings of FST 107—and thus modern sensory science—from Germany in the nineteenth century through Cornell, Harvard, Chicago, and to the University of California at Davis, and we will make some detours to England, Denmark, and Kentucky. To produce a narrative that explains how and why sensory science has taken its present form, I focus on the individuals who contributed significantly to the discipline. Despite some recent publications (Shapin 2016; Lahne and Spackman 2018), this focus is valuable partly because—to my knowledge—no one has done this in just such an alignment. Unexpected commonalities and conclusions emerge: for example, the so-far under-acknowledged and fundamental contribution of female scientists, such as Jean Caul, Elaine Skinner, Gail Civille, and Rose Marie Pangborn, to the field of sensory science. In order to show how central Rose Marie Pangborn's FST 107 class was to the field's formation, this wandering history will tend to follow the broad outlines of her syllabus (Figure 1).

FS&T 107 LECTURE, T/TH 11- 12 LAB., T/W/TH 1-5 WINTER, 1986

TU Jan 7	Introduction, History	Lab. 1	Intro., Aroma/Flavor/Taste
TH Jan 9	Food Aromas/Flavors		
TU Jan 14	" " "	Lab. 2	Aromas/Flavors
TH Jan 16	Taste		
TU Jan. 21	" , Thresholds	Lab. 3	Rel. Sweetness, Ad-lib. Mixing, Time-Intensity
TH Jan 23	Color/Appearance of Foods		
TU Jan 28	Difference Tests	Lab. 4	Color/Appearance Difference Testing
TH Jan 30	Difference Tests		
TU Feb 4	MIDTERM EXAMINATION	Lab. 5	Texture
TH Feb 6	Texture		
TU Feb 11	Rating Tests	Lab. 6	Rating Tests Incomplete Block Designs
TH Feb 13	" "		
TU Feb 18	Descriptive Analysis	Lab. 7	Descriptive Analysis
TH Feb 20	" "		
TU Feb 25	Principal Comp. Analysis	Lab. 8	Consumer Tests
TH Feb 27	Lab. vs. Consumer Tests (Guest Lecture)		
TU Mar 4	Judge Selection/Training	Lab. 9	Ketchup Lab.
TH Mar 6	Laboratory Facilities		
TU Mar 11	" "	Lab. 10	"Trouble Shooting"
TH Mar 13	Unresolved Challenges Professionalism		

FINAL EXAM: March

GUEST LECTURER: Mr. Joel Sidel, Consultant, Tragon Corp., Menlo Park, CA
(After lecture, discussion in Filper Room, 12 - 1. Bring lunch.)

FS&T 107 Reading Room, 2470 Chem. Annex, Open Mon.-Fri., 8-6 (Previous exams)

INSTRUCTOR: R. M. PANGBORN, 2471 Chem. Annex: T. A.: 2480 Chem. Annex (752-2168)

Figure 1. The 1986 syllabus for Food Science and Technology (FST) 107. Used under the Fair Use provision.

Psychophysics: a beginning

Psychophysics is a branch of psychology in which researchers have an interest in the relationships between physical stimuli and the human's sensory responses to these stimuli (Lawless and Heymann 2010). From a sensory-science perspective everything we do is related to how a human responds to a food stimulus—do you perceive one to

be more bitter, less sweet than the other? Do you like these versions of the food more or less than those versions? Therefore, psychophysics is fundamental to the field of sensory science.

The earliest work in psychophysics was in the 1800s in modern-day Germany. Ernst Heinrich Weber, who was born in Wittenberg, Germany in 1795, earned a doctorate in medicine from the University of Wittenberg in 1815 and became a professor of Anatomy at the University of Leipzig, Germany in 1818. He retired from this institution in 1871 and died in 1878 (Kruta 2008). In 1846 he published *Der Tastsinn und das Gemeingefühl* (Weber, 1846) in which he formulated his most important contribution, Weber's Law: the size of the just noticeable difference ("jnd") is a constant proportion of the original stimulus value (Figure 2). As an example of how important the jnd still is I am citing the article by Lundgren et al. (1976). This manuscript, which was part of international, interlaboratory research into sensory science originally coordinated by Rose Marie Pangborn, showed that the jnd for sucrose in 2% sucrose water was a change of 0.266% sucrose and that for 5% sucrose water the jnd was a change of 0.400% sucrose. This leads to values of k = 0.133 and k = 0.08, respectively: clearly not constant—thus Weber's Law can be seen as setting in motion a set of continuing investigations that led to psychophysics and sensory science.

Weber's Law:

$$k = \frac{\Delta I}{I}$$

Where k = a constant, the just noticeable difference (jnd)

ΔI = difference threshold

I = original intensity of the stimulus

Fechner's Law:

$$S = k \log I$$

Where S= sensation

k = a constant

I = stimulus intensity

Steven' Law

$$\varphi(I) = kI^a$$

Where Ψ(I) = subjective magnitude of the sensation elicited by the stimulus

I = stimulus intensity

a= exponent dependent on the modality

k = proportionality constant

Figure 2. Mathematical equations for Weber's, Fechner's, and Stevens' laws of psychophysics.

Weber affected the career of Gustav Theodor Fechner, who created the next building block in our story. He was born in 1801 in Gross-Särchen (now Żarki Wielkie, Poland) near Leipzig (Anonymous 2018a). Fechner studied for a medical degree at the University of Leipzig where Weber was his anatomy professor. He worked under Weber and Johann Rosenmüller, receiving a Bachelor's degree in 1819 and a Master's degree in 1823. He became a professor of Physics at the University of Leipzig in 1834, and received his PhD from the same institution in 1835. In 1839 he severely damaged his eyes while gazing at the sun and essentially had to retire. He continued his philosophical writing and in 1848 was appointed as chair of Philosophy at the same university (Heidelberger 2004). He published the first book on psychophysics in 1860, namely *Elemente der Psychophysik* (Fechner, 1860). Fechner modified Weber's Law and created Fechner's Law: the perceived sensation increases as the log of a stimulus intensity (see Figure 2). If we calculate the k values for Fechner's law for the values found by Lundgren et al. (1976) we get k = 0.133 for the 2% sucrose solution and k = 0.129 for the 5% sucrose solution, both more similar than when one used Weber's Law.

Our next German professor does not directly move psychophysics forward but he is instrumental in making the field of study known in the United States of America. In 1832, Wilhelm Maximilian Wundt was born in the town of Neckerau in the Baden area of Germany. He studied at Tübingen University (1851–1852) and then at Heidelberg, where he graduated with a degree in medicine in 1856 and worked as an assistant to the physicist Herman von Helmholtz (Allen 2016). He accepted a position as Professor of Physiology at the University of Heidelberg in 1864 and inspired by Weber's and Fechner's work he taught a course on the Principles of Physiological Psychology. He moved to Leipzig to become a professor of Philosophy and in 1879 he founded the first Experimental Psychology Laboratory in the world. His best-known book, published in 1874, is *Grundzüge der Physiologischen Psychologie*: the first book on experimental psychology (Wundt, 1874). Wundt died in 1920. Wundt was a prolific adviser and supervised 186 doctoral students during his career, one of whom was Edward Bradford Titchener, the character who moves our narrative to the United States.

E.B. Titchener was born in 1867 in Chichester, England and, while at Oxford studying biology, became interested in comparative psychology. Prior to graduation (1890), he translated the first volume of the third edition of Wundt's *Principles of Physiological Psychology* into English, but was disappointed when shortly thereafter Wundt shared with him the new fourth edition. It was only in 1904 that Titchener's translation of the fifth edition of Wundt's book was finally published (Wundt 1904). After graduating from Oxford he went to work with Wundt for his doctoral degree, graduating in 1892. He immediately moved to Cornell University in Ithaca, New York as a lecturer and was awarded a tenured professorship in 1895. His work was profoundly influenced by Wundt (and influential on American psychology), but for the purpose of our narrative his legacy is in his graduate students. Titchener, who died in 1927 in Ithaca, New York, also had a large number of doctoral students (Kardas 2014) graduating fifty-four, twenty of whom were women, which was quite notable for that era.

Among his graduate students important to the field of psychology was Edwin Garrigues Boring. E.G. Boring was born in 1886 in Philadelphia, Pennsylvania. After

graduating from Cornell University in 1908 with a degree in electrical engineering, he completed a PhD in Psychology under Titchener in 1914 (Stevens 1973). In 1922 he accepted a position at Harvard (1922), where he was instrumental in separating the Philosophy and Psychology departments and where he was the first chair of the newly formed Psychology department, from 1934 to 1936. Boring had an outsize effect on the field of psychology, through his prolific writing and large cohort of graduate students. He had a less positive effect on what would become sensory science. In his book *Sensation and Perception in the History of Experimental Psychology* (1942), he incorrectly translated the dissertation of David Paul Hänig (Hänig 1901) and "created" the so-called tongue map. According to Boring the human tongue had areas that were more or less sensitive to different tastants (e.g., the front of the tongue receives "sweetness," the back of the tongue receives "bitterness," and so on—this continues to be taught in many middle-school science classes). Generations of students could not replicate these findings and it was not until 1993—when Linda Bartoshuk went back to the primary source, Hänig's dissertation—that the error was discovered (Bartoshuk 1993). Boring had misinterpreted a figure in the dissertation and that had led him (Boring) to believe that a tongue map existed. Boring died in 1968.

Psychometrics: the first step into analyzing sensory-style data

However, of E.B. Titchener's protégés, it is not Boring who drives our narrative of sensory science forward, but rather Joy Paul Guilford, generally known as J.P. Guilford, and Stanley Smith Stevens, generally known as S.S. Stevens. Guilford was born in Marquette, Nebraska in 1897 and studied for his undergraduate degree at the University of Nebraska (Comrey 1993). From 1919 to 1921, he studied at Cornell University under Titchener and after a stint as the director of the psychological clinic at Cornell, he briefly worked at the University of Kansas (1927–1928) before receiving an Associate Professorship at the University of Nebraska in 1928. He remained at Nebraska until 1940 when he moved to the University of Southern California from where he retired in 1967, but continued to write until his death in 1987. Guilford worked mostly on intelligence testing and individual differences among people, but he was one of the first to write in the area of Psychometrics with his book *Psychometric Methods* (1936). Psychometrics is the measurement of human personalities, attitudes, and beliefs, and—as the field focused on the measurement of psychological attributes that could not be instrumentally determined—it was also key in the creation of statistical techniques to analyze the data obtained. In sensory science, these data-analysis techniques have been invaluable and have spawned a subfield named sensometrics.

S.S. Stevens was born in Ogden, Utah in 1906 and received a Bachelor of Arts degree from Stanford University, California in 1931 (Miller 1975). He then went to Harvard for a degree in Education until he took Boring's course on perception, which changed his life. Stevens changed his degree to Philosophy, received a PhD in Philosophy from Harvard in 1939, and became a professor of Psychology at Harvard in 1946. He did some excellent work in the area of psychophysics: among other accomplishments he articulated the eponymous Stevens' "Power Law" (Figure 2), which revisits Fechner's Law by showing that the perceived intensity of a stimulus is in fact related

exponentially, rather than logarithmically, to the physical magnitude of the stimulus (Stevens 1957). Like Guilford, Stevens was one of the early workers in the field of psychometrics and his 1946 article "On the Theory of Scales of Measurement" had a lasting impact on the field of sensory science (Skinner 1989; Moskowitz 2005). In this paper he stated that "measurement is the assignment of numerals to objects or events according to some rules" (Stevens 1946). He formulated the rules for nominal, ordinal, interval, and ratio scales (a typology of measurement and analysis), which continue to shape the thinking and teaching of sensory evaluation courses like FST 107 (Matheson 2008). In 1964 Stevens became the Harvard Professor of Psychophysics, named in honor of Fechner. He died in 1973 in Vail, Colorado while attending the Winter Conference on Brain Research.

Not all stories are directly linear: slightly before Stevens and Guilford began their influential work, L.L. Thurstone, "the father of psychometrics," began to develop the foundations of a theoretical approach to measurement in his 1927 "A Law of Comparative Judgment." L.L. Thurstone was born in 1887 as Louis Leon Thünström in Chicago, Illinois (Guilford 1953). He too attended Cornell University to study electrical engineering, but soon changed to mechanical engineering. Thurstone's interests in sound led him to sound recording for film, which led to a short working relationship with Thomas Edison. Although Thurstone took a position with Edison upon graduation from Cornell in the spring of 1912, he only worked there for a very brief period. In the fall of 1912 he went to the University of Minnesota as an instructor in Descriptive Geometry and Drafting. While at Minnesota he took courses in Psychology. In 1914, he began a PhD program in Psychology at the University of Chicago. In 1915, he accepted an assistantship in the Division of Applied Psychology at the Carnegie Institute of Technology in Pittsburgh. He continued to work at Carnegie even after he received a doctorate in Psychology in 1917 from the University of Chicago, remaining in Pittsburgh until he eventually attained the rank of professor. In 1924 he returned to the University of Chicago, where in 1927 he became a professor of Psychology (Thurstone, 1927). One of his key contributions was the development of statistical techniques for multiple factor analyses of human performance on psychological tests—analyses that are a key tool in modern sensory science. As we shall see, Thurstone was not only important in sensory science as an early psychometrician, but was actively involved in the earliest work on consumer testing. He retired from the University of Chicago and then relocated his laboratory to the University of North Carolina, Chapel Hill. He died in North Carolina in 1955.

Discrimination testing

At this point I have shown the foundations of psychophysics and psychometrics—all driven by university professors. These fields are foundational, theoretical areas for sensory science leading to the actual techniques currently used in the field such as discrimination testing. In discrimination testing the sensory scientist determines if two relatively similar samples can be discriminated in "blind" conditions. The question might be: "Can we reformulate this soda using a different sweetener without the consumer being able to tell the difference?" A discrimination test with enough statistical

power will allow the sensory scientist to determine whether this reformulation will be noticed by the consumer (Lawless and Heymann 2010).

The history of the first discrimination tests takes us on a detour into the early twentieth-century alcoholic beverage industry. We begin with William S. Gosset, an employee of the Guinness Brewery in Dublin, Ireland, who in 1908 published the first method of statistical hypothesis testing as "The Probable Error of the Mean" under an employer-required pseudonym (Student 1908)—generally known as the "*t*-test." In sensory science this test forms the basis of much everyday practice, since we use many panelists and need statistics to see the needle in the haystack. However, the *t*-test is a general statistical test, and is used far beyond sensory science. The first, modern sensory test would also emerge from the alcoholic beverage industry, several decades later.

The so-called "triangle test" for reliably discriminating food samples was invented, independently, in the United States at the Seagram's Distillery in Louisville, Kentucky in 1941 (Peryam and Swartz 1950) and in Denmark, at the Carlsberg Brewery in Copenhagen, Denmark in 1943 (Bengtsson and Helm 1946). In this test the panelists receive three samples, of which two are identical and one is different. They are asked to identify the odd sample. If conducted appropriately, the probability of a human subject guessing the odd sample correctly is one in three, and the data can quite conveniently be analyzed via standard statistical methods (Lawless and Heymann 2010). This was a key innovation at Seagram's, as the results of these tests led directly to management-endorsed changes in product formulation (Peryam 1989). At Seagram's, in 1941, Peryam also invented a related method: the "duo-trio" discrimination test. In this test the panelists again receive three samples, but one is marked as a reference sample, while of the unknown samples one is like the reference, and the other is not. Panelists are asked to identify which sample matches the reference sample. In this case, the probability of guessing the correct matching sample is one in two and the data can again be analyzed using standard statistics. These two tests formed the basis of a new way of working with food products by allowing food product developers to use the objective data derived from human panelists to formulate their products.

Consumer sensory science

David Peryam, the inventor of the triangle and duo-trio discrimination tests, acts as the bridge between discrimination testing (*objectively* determining whether two products are noticeably different) and consumer testing (determining actual consumers' *subjective* liking for products). David Roger Peryam was born in Encampment, Wyoming in 1915 (Kroll 1989). He obtained a BA degree in Psychology from the University of Wyoming and then in 1940 an MS in Psychology from the Ohio State University, Columbus, Ohio. He was hired to work for Seagram's Distillery, where he invented discrimination testing (as mentioned earlier). During his nine years at Seagram's he developed the first industrial program using the sensory perception of flavor as a guiding principle. During World War II Peryam saw combat in the Navy, returning to Seagram's at the end of the war (Peryam 1989). In 1949, Peryam became Chief of the Food Acceptance Branch of the Armed Forces Quartermaster's Food and Container

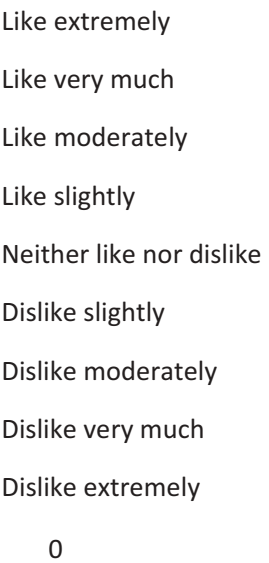

Figure 3. The word anchors for the 9-point hedonic scale.

Institute (QMF&CI) in Chicago, Illinois, where he remained until 1964. During that time he completed a PhD from the Illinois Institute for Technology. Peryam received an American Standards and Testing Materials Committee E-18 (ASTM) Sensory pioneer award in 1989, and died in Chicago, Illinois in 1992.

An early study headed by Peryam at QMF&CI—and probably the most influential for sensory science—was to create a "liking scale" to use on army personnel as a tool to improve the quality of army rations. After a great deal of research the now widely used "9-point hedonic scale" was created (Figure 3). The scale points (adjectives such as "extremely," "very much," "moderately," or "slightly") were chosen since they differed by about the same psychometric amount from one another, and thus the scale performed as a true category scale (Peryam and Girardot 1952). In 1955 Peryam and L.L. Thurstone published a paper on the development of the 9-point hedonic scale (Jones, Peryam, and Thurstone 1955). They had considered 11-point versions—nixed due to the fact that one could not neatly type the eleven categories across a standard sheet of paper (Peryam 1989)—as well as an 8-point unbalanced scale, about which Thurstone wrote to Peryam: "considering the kinds of foods that the Army deals with, I suspect you will be better advised to keep the full range of dislikes," the general unpleasantness of army rations being well known (Meiselman and Schutz 2003). The creation of the 9-point hedonic scale opened up the possibilities of having actual consumers—the target audience—indicate their degree of liking for products and allowed product developers to get information directly from real consumers. And, essentially, all of Rose Marie Pangborn's first publications use the 9-point hedonic scale to determine consumers' liking for canned fruits (apricots, peaches, and Bartlett pears: Valdes 1956; Simone et al. 1956; Pangborn and Leonard 1958).

Flavor profiling and descriptive analysis

In 1957 David Peryam and Beverly Kroll co-founded a food research consulting company: Peryam and Kroll. This move into private consulting was uncommon at the time and leads us to the next major innovation in sensory science, descriptive analysis—interestingly driven by consulting companies rather than universities or directly by the food industry. Arthur D. Little (ADL) is the world's first and oldest consulting company and in the late 1940s it had a food research group headed by the physicist Ernest Crocker, "the man with the million-dollar nose" (Caul 1989). In 1945 the food research group at ADL hired Jean Caul.

Jean Frances Caul was born in 1915 in Cleveland Heights, Ohio. She received a BS in Chemistry and Physical Education from Lake Erie College, Painesville, Ohio in 1937 and an MS in Physiological Chemistry from the Ohio State University (OSU). She tried to enroll in a PhD in Chemistry at the OSU but was told that "women did not make good chemists." She persisted and went to the Department of Physiological Chemistry, Toxicology and Materia Medica at OSU (Chambers 1989). In 1942, she was the first female to receive a PhD from this department. After a short stint at the Borden Company in Ohio she moved to Boston, MA to work at ADL. In 1967 she left ADL to become a faculty member at Kansas State University, Manhattan, KS. There she had the distinction of being named the first female Distinguished Professor. She also received an American Standards and Testing Materials Committee E-18 (ASTM) Sensory pioneer award in 1989, and died in Manhattan, Kansas in 2009.[1]

Working with her colleagues—Ernst Crocker, Loren (Johnny) B. Sjöstrom, a chemical engineer, and Stanley Cairncross, a pharmacist—Caul "found that we all detected integers[2] in aromas and flavors; that the integers were not all of the same intensity in one sample; that they were perceived separately; and that they seemed to be supported by a complex" (Caul 1989). The problem was that the sensory toolkit at that time used either discrimination tests—most useful with small differences among products—or consumer hedonic testing—useful when you wanted to know which products were liked by target consumers, but not useful in determining how the products differed in their sensory attributes. The ADL group, and specifically Jean Caul, felt that there should be a way to evaluate all the attributes associated with a food product in a clear and concise fashion. They developed the Flavor Profile™ (Caul 1957), the first method of descriptive analysis in foods. This consensus sensory technique attempted to evaluate all aspects of a product in a defined sequence of aroma, taste, flavor, mouth feel, aftertaste and "amplitude." The technique used an unusual scale (Figure 4) and due to the ")(" could not be statistically analyzed but, as all evaluations were done through group consensus, all panelists participating in Flavor Profiles were trained to identify all needed aromas, tastes, flavors, and aftertastes as well as the "amplitude" (Lawless and Heymann 2010). The amplitude was defined as the degree of balance and blending of the flavor. The major innovations of the Flavor Profile were, first, the possibility of describing all the sensory attributes of a product, and, second, the use of panelists who had been extensively trained in each of these attributes. The training ensured that all the panelists spoke the same language and were using the scales in the same way.

One of the early companies adopting the Flavor Profile™ was the General Foods (GF) Corporation in Hoboken, NJ, under the auspices of Elaine Skinner. Elaine Zlobik

MALT BEVERAGE X

Aroma		Amplitude 3
	Intensity	
Hop fragrance	2	
Fruity (apple)	2	
Sour	1.5	
Yeast	)(	
Malt	1	
Phenylacetic acid (honey)	1	

Flavor-By-Mouth		Amplitude 1
	Intensity	
CO_2 tingle	high	
Salt	1	
Sweet	1	
Sour	2	
Fruity (winy)	1	
Bitter (metallic)	3	
Malt	)(	
Yeast	1	

Others: Astringent

Aftertaste: Bitter
Astringent
Dry throat

Figure 4. A Flavor Profile™ for a Malt Beverage (Reprinted with permission from Caul, 1967).

Skinner, born in 1927 in Wilkes Barre, Pennsylvania, received a BS degree in 1951 from the College of Misericordia in Dallas, Pennsylvania. She went to General Foods (GF) as a Test Kitchen Employee in 1951 and retired thirty-five years later as a very respected sensory scientist. She died in 2003 (Obituary 2003a). One of her earliest assignments at GF was to implement the triangle test—based on Peryam and Swartz's newly published 1950 paper. She was instrumental in building the team at GF in flavor research into a world-renowned entity (Skinner 1989). Gail Vance Civille has said that working for Elaine Skinner allowed her to "claim (a) graduate degree in graduate sensory evaluation from the Elaine Skinner School of Sensory Evaluation" (Civille 1989). Elaine Skinner received a Founder in Sensory Science award from ASTM in 1989.

The Flavor Profile™ was trademarked by ADL, and the lack of a true rating scale made it impossible to do any statistical analyses on the data or to compare between analytical sessions or different flavor panels. It therefore did not achieve wide adoption (except in water-treatment facilities, where it is used to this day; Bartels and Burlingame 1986). This was not seen as an impediment to its use by ADL, but others found the limitations frustrating (Sidel 2018). In particular, Herbert Stone and Joel Sidel, researchers at the Stanford Research Institute (SRI), took the innovation of a well-trained panel from the Flavor Profile™ method, and used it to create the "Quantitative Descriptive Analysis" (QDA™). Herbert Stone was born in 1934 in Washington, DC and received

a BS in Food Science from the University of Massachusetts, Amherst, in 1955. (Stone 2018). After serving in the US Army in Korea from 1955 to 1957, he returned to Massachusetts and obtained an MS in Food Science. He joined SRI in 1962 and received a PhD from the University of California, Davis in 1963. At SRI he established a sensory testing facility working on human behavior while emphasizing consumer products. Between 1965 and 1970 he started the research that eventually led to QDA™ (Stone et al. 1974). In 1972, he hired Joel Sidel to be part of the SRI sensory program. Joel Sidel was born in 1939 in Providence, Rhode Island (Sidel 2018). He received a BA from Clark University, Worcester, Massachusetts (1963) and an AM from Northeastern University, Boston, Massachusetts (1966). Both degrees were in psychology. He then worked for the US Army Natick Laboratories (1965 to 1968)—part of the QMF&CI—in Natick, Massachusetts and was Head of Sensory Evaluation at Hunt Wesson Foods, in Fullerton, California, from 1968 to 1972.

Stone and Sidel removed the *consensus scoring* of the samples from the Flavor Profile, while still requiring the panelists to determine through consensus the sensory attributes they needed to evaluate for the specific product set. As many sensory attributes as possible were anchored by physical reference standards (Lawless and Heymann 2010) and Stone and Sidel asked the trained panelists to *individually* rate the samples using a line scale, producing statistically analyzable data. Additionally, they introduced controls for variability between subjects: in order to determine panelist consistency they had panelists evaluate the same samples multiple times. In their original publications they used four to six replications but over the years this has standardized to three (Peltier et al. 2018). The fact that the data were amenable to statistical analyses and that one could evaluate panelists' performance meant that sensory scientists could correlate their sensory descriptive analysis data with data obtained from instrumental analyses or from other groups.

Shortly after the development of QDA, Stone and Sidel used it as the basis of the Tragon Corporation in 1974—another sensory consulting company. The name is a portmanteau of "trattoria" (marketplace in Italian) and "oregon" (signifying life). Tragon was sold in 2008, and today Joel Sidel is a Senior Consultant for Curion Insights (the successor company to Tragon Corporation) and Herb Stone has been active as President of IFT and is also doing some sensory consulting.

Following the trend, Gail Vance Civille, who worked extensively with Elaine Skinner at General Foods from 1965 to 1970, left to start her own sensory consulting company, Sensory Spectrum, and trademarked the Spectrum™ Method. Born Gail Vance in Brooklyn, New York in 1943, she received a BS in Chemistry from the College of Mount St Vincent in Riverdale, New York (Anonymous 2018b). She found employment at General Foods Corporation in 1965, where she met her husband. The Spectrum™ method borrowed heavily from both Flavor Profile and QDA™, but added further refinements. The major one was that panelists were trained extensively to use general sensory lexicons and so-called absolute scales for each attribute rated, rather than developing product- or category-specific lexicons. Civille felt that the data were more absolute and actionable than the QDA™ data, which were viewed as relative because each panel was free to score the consensus-generated attributes on the linear line scale as they wanted. For a discussion of what this means to the food industry today see Lahne (2018).

The Flavor Profile, QDA, and the Spectrum method are all sensory descriptive methods; they aim to use the human panelist's senses to describe the sensory attributes of a product. For example, in one of the early academic uses of a descriptive technique, Larson-Powers and Pangborn (1976) used the technique to describe the sensory differences due to the use of sucrose, aspartame, or cyclamate as a sweetener in fruit-flavored beverages as well as in fruit-flavored gelatin desserts. They found that drinks sweetened with sucrose or with aspartame could be characterized as "sweet-clean," and those sweetened with cyclamate or with saccharin as "sweet-chemical" and "bitter." Gelatins containing synthetic sweeteners generally were more astringent, bitter, and sour, with less strawberry flavor, and were significantly less hard, springy, and viscous than those sweetened with sucrose.

Role of the University of California at Davis

At this point we have all the pieces of what is now sensory science: psychophysics and psychometrics, discrimination testing, consumer sensory testing, descriptive analysis, and the use of statistics to analyze the data. However, these disparate methods were present at the same historical moment, but not necessarily cohesively and concisely standardized into a science. I argue that the University of California at Davis had the key role in creating this cohesion and subsequently disseminating sensory science worldwide.

On January 16, 1919 the 18th Amendment to the United States of America's constitution was ratified and, due to the Volstead Act, the sale of alcoholic beverages was prohibited starting in 1920. This law decimated the thriving California wine industry. Prohibition did not lead to a decrease in alcohol abuse and had a number of unintended consequences such as a rise in organized crime (Keene, Cornell, and O'Donnell 2012). As a result, the ratification of the 21st Amendment to the US Constitution on December 5, 1933 repealed the 18th Amendment. By this point the California wine industry was struggling (Lapsley 1996). The University of California, then with only one campus in Berkeley, CA, had been mandated by the State Legislature to do research in viticulture and enology in 1880. This research had moved to the University Farm, later (1959) to be known as the Davis campus of the University of California, before the onset of Prohibition. After 1920, the Viticulture and Enology department changed its name to the Viticulture department to eliminate research on now-taboo enology but the faculty did continue to do work on raisin and table grapes (1996). At Repeal, "enology" was added back and the Department of Viticulture and Enology hired an enologist to help the wine industry recover from Prohibition.

That individual was Maynard Amerine (Borg 2018). Maynard Amerine had been born in San Jose, California in 1911 but grew up in Modesto, California. In 1934, he started working as a lecturer and researcher at the University Farm in Davis, California. Amerine received his PhD in Plant Physiology from the University of California in 1936 and was immediately promoted to assistant Professor. He became a full Professor in 1952 and was the department chair of Viticulture and Enology from 1957 to 1962. He retired in 1974, received a Founder in Sensory Science award from ASTM in 1989, and died in St Helena, California in 1998.

He was asked to work with Albert Winkler, the department chair and renowned viticulturalist, to determine which wine grape cultivars were best suited for specific

regions of California. Originally Amerine and Winkler envisioned the wine-quality work to encompass both climate and soils but it was too complex and they chose to work only on the climate aspect. After years of work and over 6000 five-gallon lots of wine, they published Winkler and Amerine (1944), while Amerine was in the US Army Chemical Corps in India during World War II. The publication uses the wine-quality and climate work from the previous decade to identify which grape varieties should be grown in which areas of California.

Amerine was charged with improving wine quality in California, and to do so he had to find a way to evaluate human opinion of wine quality. An early effort involved the creation of three separate 100-point wine-quality scorecards, one each for red and white table wines and one for dessert wines (Cruess 1935). He soon realized that the panelists only used a small portion of the 100-point scales and so created the so-called Davis 20-point Wine Quality Score Card (Figure 5) (Amerine, Roessler, and Filipello 1959). This metric deemed wines to have high quality if they were free from defects and "true to type." Through this work Amerine became interested in the early work on psychophysics, psychometrics, and discrimination testing.

At Davis, the department of Viticulture and Enology and that of Food Science and Technology (FST) are entirely separate entities. In 1955, the FST department hired a young food scientist named Rose Marie Valdes as a research scientist and prospective PhD student. Rose Marie Valdes had been born in Las Cruces, New Mexico as Rosa Maria Valdes in 1932. She received a BS degree from New Mexico State University, which was followed in 1955 by an MS degree from Iowa State University (Noble, Grivetti, and Whitaker 1990). Rose Marie married Jack Pangborn in 1956 (Obituary 2003b) and as Rose Marie Pangborn she became a lecturer in the Food Science and Technology department in 1963, an Associate Professor in 1968, and a full Professor in 1972. She was an Associate Dean of the College of Agriculture and Environmental Science from 1972 to 1974. It is interesting to note that she never completed the PhD degree for which she first came to UCD. She received a Doctor Honoris Causa from the University of Helsinki, Finland in 1984. Similarly to David Peryam and Jean Caul, she received a Pioneer in Sensory Science award from ASTM in 1989.[3] She died in Davis, California in 1990. Through her teaching and writing, Pangborn would almost single-handedly create the template for how a modern sensory scientist conducts her/himself professionally.

Emil Mrak, the FST department head in the 1950s, had been involved with work by the QMF&CI in Chicago, IL during World War II. Based on these experiences, he was eager to institute a course to teach FST students about sensory techniques (Amerine et al., 1959). In 1960 the FST department decided that it needed a new, stand-alone course which it called FST 107: "Sensory Evaluation of Foods." Rose Marie Pangborn, Maynard Amerine, and Edward Roessler were charged with creating the content. Of the three, only Rose Marie Pangborn was a member of the FST department (Roessler was a professor of statistics on the Davis campus). The first teaching assistant was Herbert Stone (Stone 2018). And most of what follows on the history and practice of FST 107 is based on personal communications with him.

"Sensory Evaluation of Foods" was not completely conceived by the beginning of the quarter—the broad outline was in place but not all the specifics. This is unusual: in most instances when a new course is planned the syllabus is created prior to the start of the

SCORECARD

Name _____

Name or no.					
Appearance 2					
Color 2					
Aroma & bouquet 4					
Acescent 2					
Total acid 2					
Sugar 1					
Body 1					
Flavor 2					
Astringency 2					
General quality 2					
Total					

Fig. 8. According to the Davis 20-point scale, to achieve a score of 17 to 20, wines must have some outstanding characteristic and no marked defect; 13 to 16, standard wines have neither an outstanding character nor defect; 9 to 12, wines are of commercial acceptability but with a noticeable defect; 5 to 8, wines are of below commercial acceptability; 1 to 4, wines are completely spoiled.

Figure 5. The Davis 20-point wine quality score sheet. Used under the Fair Use provision.

course but in this case it was created as the course proceeded. The three professors and Stone would meet weekly to plan the laboratory experiments and to refine the lecture material. After the first few years the course was entirely taught by Rose Marie Pangborn. It became clear very early that there was a need for a textbook and in 1965 Amerine, Pangborn, and Roessler published *Principles of Sensory Evaluation of Food* (Amerine et

al., 1965). This book was viewed as the bible for sensory science for the next thirty-five years.

According to Howard Moskowitz (2004)—another sensory and consumer scientist par excellence—Pangborn was crucially important because she bridged the gap in sensory evaluation from model systems to real foods and recognized vast differences in hedonic responses among consumers to the same foods. Uniquely among sensory scientists at the time, Pangborn went to the consumer "where they ate," so to speak. For years, she used the California State Fair as a location to find consumers and had over 23,000 people consumers indicate their liking for canned apricots, peaches, and pears as well as for ice-creams (Valdes 1956; Simone et al. 1956; Pangborn, Simone, and Nickerson 1957; Pangborn and Leonard 1958). Additionally she taught FST 107, which Moskowitz agrees was foundational to creating the modern conception of the sensory scientist.

The importance of FST 107 can be traced to two reasons. The first was a decision by Rose Marie Pangborn that she would freely share the syllabus, laboratory manual, and lecture notes with anyone who asked, as long as they either came to the Davis campus for a visit or invited her to their campus for a visit. The result of this is that—in my personal experiences with sensory science courses worldwide—just about all sensory courses have fewer than three degrees of separation from the design of FST 107.[4] The second "and more subtle" reason, according to Howard Moskowitz, is "Rose Marie Pangborn, a founder in the field and a purist. Pangborn trained many students at the University of California, Davis, and in some ways single-handedly created the academic field. Pangborn was part scientist, part teacher, 100% rigorous, but with an inspiration to introduce her students to the scientific method" (Moskowitz, Beckley, and Resurreccion 2012). Pangborn throughout her career strove to bring together in a cohesive whole all the disparate sensory techniques already described . Many of her students—or students taught from the mold of FST 107—from the 1960 to late 1980s went on to become sensory scientists in industry and her thinking and approach can be seen across companies and countries. Additionally, she was a force of nature who in equal measure inspired terror and adoration on a professional level. She demanded and received excellence from her students and her expectation that a sensory scientist would act professionally was nonnegotiable. As one of her teaching assistants in 1982 I can attest to the expectation of perfection. If anything was not perfect, then you just did it again and again and again. Despite her very exacting standards she inspired devotion and respect. "Pangborn was clearly a mother figure, but one who spared no criticism when her student departed from the path of rigid, pure, and puritanical science" (Moskowitz, Beckley, and Resurreccion 2012).[5]

Conclusion

Sensory science is:

> . . . a relatively young research area that in the first three decades of the 50 years of its existence has mainly been pre-occupied with establishing itself as an "objective" science. A science that, although dealing with subjective data, produced reliable and reproducible outcomes. The influence of psychology came mainly from psychophysics and was limited to the improvement of the use of "the human measuring instrument and to the

development of better scaling techniques and better methods to exclude 'subjective' influences." (Köster 2009, 71)

I have shown how the different people and strands of sensory science have evolved over the last 150 years and it is fascinating to me that the field came about through universities, industry, and consulting companies. It is also quite astonishing that many of the early innovators were woman in a time that making themselves heard in professional fields was quite difficult. I feel that I have made the case that the unification of what is today sensory science can be directly traced back to the UCD food science program and Rose Marie Pangborn. In many ways I believe her iron will and strong personality was the driving force in creating Sensory Science.

Notes

1. An excerpt from an Edgar Chambers IV e-mail (Chambers, 2018): "Her speech at the 2003 Boston Pangborn, when she was in the beginning stages of Alzheimer's was her last public address. She had been telling people at the retirement community she was going to speak in Boston, but no one believed her until I arrived to help her pack and take her to Boston. The social worker for the retirement community told me I could not be serious—that didn't I understand she had Alzheimer's and was not really going to speak at a conference in Boston. I assured her that Jean was speaking at the conference and that we had been working on her speech for several months. She told me I couldn't be serious; didn't I know that Jean had even forgotten how to dress appropriately. She said 'She sometimes even wears a jumper been made from floral curtains!' I laughed and said she had those made when she left Boston and moved to Manhattan from the curtains in her home. She liked them so much she sometimes wore them to work and I had seen her wear them at professional meetings. The social worker was incredulous!"
2. Jean Caul's use of the word integers is confusing. We think she meant individual sensory attributes (sweet, floral, astringent, etc.) and that these came together to form a complex sensation.
3. In 1989 ASTM also awarded a Pioneer award to Alina Surmacka Szczesniak, She spent her entire career at GF. Her life story—including studying at underground institutions in Poland during World War II and graduating *cum laude* from Bryn Mawr College after only a few years in the USA—deserves to be told. The other person awarded a Founder award in 1989 was Howard Schutz. His impact on the field of consumer sensory testing deserves its own manuscript too.
4. When I sent one of the co-editors (Lahne from Virginia Tech. University) of this issue of the journal a copy of Figure 1, he replied to my email with "Amazing! That looks so much like my syllabus. It's so cool that I rushed out to show it to our current sensory PhD student. . .."
5. I strongly feel that histories of Howard Moskowitz and Ann Noble should also be added by someone at some point.

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