SENSES AND SENSATION:
CRITICAL AND PRIMARY SOURCES

Volume 3

BIOLOGY, PSYCHOLOGY AND NEUROSCIENCE

Edited by David Howes

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Introduction: On the Individuation/ Integration of the Senses in the Fields of Biology, Psychology and Neuroscience—An Orthogonal View

DAVID HOWES

The previous two volumes in this compendium explored the contributions of the social science disciplines of geography and anthropology (vol. 1) and history and sociology (vol. 2); the present volume takes in the contributions of the natural science disciplines of biology, psychology, and neuroscience to our understanding of the senses and sensation. There already exists a copious literature on sense perception in these three areas of research (e.g. Basbaum et al 2008; Shepherd and Grillner 2010; Mather 2016; infra note 6). So, rather than simply summarize that literature, this volume breaks new ground by setting it in historical and cross-cultural perspective. This orthogonal approach has the merit of *de-normalizing* the assumptions, theories and findings of the "natural sciences" of perception.

The idea of de-normalizing is suggested by Thomas Kuhn's account of "normal science" in *The Structure of Scientific Revolutions*. He encapsulated his theory with a somewhat unsettling quote from the philosopher Alfred North Whitehead: "A science that hesitates to forget its founders is lost" (1970: 138). By this Kuhn, a historian of science, meant to underline the dependence of scientific knowledges on sets of assumptions or "paradigms" which are historical, yet ignore their own historicity. Indeed, forgetting earlier paradigms is the condition of success for "normal science." As Steve Fuller puts it: "science cannot progress unless its practitioners *take for granted* that it rests on secure epistemic foundations … they should be willing to 'forget' the past in the sense of *discarding* it when necessary" (2000: 302 n. 89). Only in "revolutionary" moments, when the "exceptional phenomena" pile up and can no longer be boxed in by the prevailing paradigm, does (veritable) innovation take

precedence over repetition and tradition, according to Kuhn, and this is usually thanks to a few stalwart individuals who—at the risk of being branded misguided, unscientific, lunatic, or worse—propose new paradigms that can accommodate the recalcitrant phenomena.

The approach advocated in this volume is somewhat more revolutionary than Kuhn's, however, because it is radically anti-positivist and anti-presentist in orientation. It insists on *remembering*—that is, on confronting the prevailing (contemporary) paradigms with historical facts (i.e. allegedly outmoded paradigms going back to Aristotle) and with cross-cultural data (i.e. non-Western or indigenous biologies, psychologies, and notions of the brain) that fall without the ken of "normal (Western) science." Otherwise put, this volume seeks to resituate the history and philosophy of science (including Science and Technology Studies) within the larger interdisciplinary purview of sensory studies. Sensory studies involves a cultural approach to the study of the senses and a sensory approach to the study of culture, including the natural sciences. It treats the senses and sensations as both object of study and means of inquiry.

Briefly, the objective of this volume is to arrive at a resolutely historical and cross-cultural, multi- and inter-modal theory of how the senses work. To this end, in Overture I: Sensory Individuation, we embark on an investigation of the boundaries of the five-sense model of the sensorium by examining the postulate of "the sixth sense," which has assumed many different guises down through history. In Overture II, we turn to explore breaking research within psychology and neuroscience on the sensory integration of the brain. This research calls into question the whole project of individuating the senses, and institutes a radically relational, interactive understanding of how the senses function in its place. The latter understanding is consonant with the emphasis on relationality and the interactivity of the senses within sensory studies.

PART I: FOUNDATIONS

Overture I: Sensory Individuation

In the early modern period, the term "sensorium" was used to denote the "percipient center" or "seat of sensation in the brain of man and other animals," and it is still used in this sense today.[1] But there is another, occulted meaning of the term which needs to be recuperated. In the same period, the concept of the sensorium was extended to include the circumference of perception. In illustration of the latter point, the *OED* quotes one usage from 1714: "The noblest and most exalted Way of considering this infinite Space [referring to 'the Universe'] is that of Sir Isaac Newton, who calls it the *Sensorium* of the Godhead," and another from 1861: "Rome became the common sensorium of Europe, and through Rome all the several portions of Latin Europe sympathized and felt with each other."

Refiguring the Sensorium

The notion of the *sensorium* is thus a very capacious or *holistic* one. Thanks to its holism it can stand for "the five senses," which is one way of construing the totality of percipience, but nothing prevents it from being extended to other constructions, other models, such as "the two senses" (see below) or "the seven senses" (see Jütte 2005: 54–60), and so forth. This is a major advantage from the historical and cross-cultural (i.e. sensory studies) standpoint advocated here, since it enables us to incorporate the concepts of other cultures and other historical periods into our discussion of the senses and sensation. For example, the Hausa of Nigeria have one word for sight (*gani*) and another (*ji*) for hearing,

conscience. (It is appropriate to speak of "conscience" here since the potential for using the senses immoderately was always very much on the classical mind, while the potential for using them sinfully weighed just as heavily on the medieval and early modern mind [Newhauser 2007; de Boer 2013].) The birth of "consciousness" or cognition as we know it would have to await Descartes, who famously "call[ed] away all [his] senses" to discover the truth of his own existence: *cogito ergo sum*, "I think therefore I am" (quoted and discussed in Synnott 1991: 70). It helped that the anatomical basis of the doctrine of the inner senses had been discredited by advances in physiology.

Even so, aspects of the Aristotelian account of sentience survived the Cartesian censure of the senses, and were (re)affirmed with a vengeance during the Age of Reason, which was also, it should be remembered, the Age of Sensibility. One of those aspects was the common sense, *sensorium commune*, which was transmuted by the thinkers of the time into a generalized notion of "sensibility" (Barker-Benfield 1992; Vila 1998; Riskin 2002).

The Multiplication of the Senses in the Eighteenth Century

The eighteenth century was something of a watershed in the history of the senses in view of the number of new senses that were put forward for discussion during this period—common sense being just one of them. The Irish/Scottish philosopher Frances Hutcheson, for example, argued for the existence of both a moral sense, which would present the mind with an idea of virtue when perceiving a benevolent act, and an analogous sense of beauty, which would call up notions of beauty when perceiving harmonious configurations. To these, he later added an eighth "public" sense, which responded to the happiness and suffering of others, and a ninth—the sense of honour. In these sensory multiplications, Hutcheson was influenced by contemporary notions of an innate sense of public good or private virtue as communicated by such writers as the third Earl of Shaftsbury and the Cambridge Platonist Henry More (James Moore personal communication).

As James Moore details in the following quotation, these notions were taken up by a series of philosophers, particularly those associated with the Scottish Enlightenment.

> David Hume agreed that virtues and vices are determined by a moral sense; but Hume resolved the moral sense into sympathy with others, with qualities of character that are useful and agreeable to self and to others. Hume's scepticism with regard to the moral sense was repudiated by Henry Home who offered his own theory of the moral sense as a sense of remorse and dread of merited punishment. Adam Smith followed Hume in making sympathy, not the moral sense, the source of moral distinctions; but Smith considered utility to be merely one of the considerations that prompt us to sympathize with others. Adam Ferguson disagreed with his friends Hume and Smith; he agreed rather with Hutcheson in locating the origin of moral distinctions in a moral sense; he thought that the quality most esteemed by the moral sense was active intelligence, particularly when intelligence is exercised in the service of the public. Other Scottish philosophers—Thomas Reid, Dugald Stewart and Sir William Hamilton—replaced the moral sense by a more general theory of common sense. This was not a sixth sense or a special faculty of perception; it referred rather to the human capacity to apprehend reality unmediated by ideas; it was the precondition of perception, memory and the exercise of all the intellectual and active powers. (James Moore, personal communication; see further McCosh 1875; Broadie 2003; Kivy 2003; Moore 2004)

Without trying to fathom all the intricacies of these "internal senses" (as they may be called to distinguish them from the "inner senses" of the Middle Ages), a few general observations may be made. The inwardness of the "internal senses" points to a deepening sense of the interiority of consciousness, of the self. Furthermore, they are all forms of "feeling" rather than thinking or reason, which is consistent with the "sentimental empiricism" of the period (see Riskin 2002) in contrast to the rational empiricism of today. Third, they are all very sociable rather than physical, particularly the moral sense, and that of the public good. However, the eighteenth century understanding of the *sociability* of the senses (and perception) did not endure for long, and it is the Scottish thinkers who were responsible for this. Whereas the moral *valuation* and moral *use* of the senses was intrinsic to classical and medieval sensory practice, the Scottish philosophers divorced the moral sense from the other "physical" senses by constituting it as distinct. This opened the way for the amoralization of perception—that is, the reduction of sensation to "information-processing," or, simply, "patterns of neural activity."

Beneath the Five Senses

Besides the world "beyond the five senses," there is a world "beneath the five senses" (the visceral, the molecular)[10] to which modern science has increasingly sensitized us. Here is how Howard C. Hughes describes that world:

> There is also the world inside our bodies, and there are sensory organs that provide information crucial to internal bodily states. Our senses of balance, of body motion, and of posture, depend on sensory organs in the inner ear, in our joints, and in muscles. There are even organs that monitor such things as the levels of carbon dioxide in the blood, blood pressure, and blood glucose levels. These organs provide the brain with information essential to life, but they do not produce conscious sensory experiences (otherwise, people would be aware of the onset of hypertension, and it would less frequently go undetected). (Hughes 2001: 5)

An account of how this inner world was produced—that is, of the scientific practices which generated the physiological discoveries that gave definition to what we shall here call the "interoceptive" (as distinct from "inner" or "internal") senses of balance, body motion, etc.—is provided by Nicholas Wade in his classic essay, "The Search for A Sixth Sense" (2009). These discoveries were perhaps inevitable, for we saw how Aristotle blurred certain distinctions in his account of the sense of touch, and already by the eleventh century there were suspicions (voiced by Avicenna) concerning the unity of the haptic sense (Kemp 1990: 46). Forced unions are bound to dissolve in time—especially when the cosmology which made them sensible or necessary no longer holds. There were but four elements in ancient Greek cosmology and that arrangement (with minor variations, the postulation of a fifth element, ether, for example) held for centuries, but Mendeleev's Periodic Table of the Elements puts the number at 118 and any connection between the senses and the elements has been severed (see Atkins 1997 and Illich 2000 on the significance of this re-numeration).

While there are a number of earlier intimations of the "interoceptive senses" (see Heller-Roazen 2007: 163–178, 237–251), it appears to have been the eighteenth century's intense focus on *feelings* that brought the matter to a head, and precipitated the physiological discoveries of the nineteenth century. Take the case of kinaesthesia:

> Kinaesthesia, the sense of bodily movement, had been studied before the nineteenth century under a variety of other names, including "inner sense" and "organic" or "visceral" sensibility—all referring to those unclassifiable sensations that could not be traced accurately to one of the five known sense organs, but seemed to originate from the undifferentiated mass of the viscera. It was not until the early nineteenth century, however, that "muscle sense" was officially declared a "sixth sense" in its own right. (Çelik 2006: 159)

The dissolution of the sense of touch into a panoply of senses—pressure, temperature, pain, as well as kinaesthesia, proprioception, balance, and so on—was only to be expected. Not so expected, perhaps, is the way vision has come to be dismembered by contemporary scientists into separate senses for light and color (and arguably, separate senses for red, green, and blue); or the way taste has fragmented into separate receptor organs for sweet, salt, sour, bitter (and for the fifth flavor, umami); or, the way smell has been broken down into multiple receptors (see Jones 2006: 45 n. 26 and figure 2). "The more we study the structure of our sense organs, the more senses we appear to have" (Durie 2005: 35). A conservative estimate would put the number of senses at 10, but it is generally accepted by neurobiologists that our senses number 21, and radical estimates put the number as high as 33 (see Table 0.1).

These figures confirm Vinge's point: "The number and order of the senses are fixed by custom and tradition, not by nature" (2009: 107). No doubt there is a widespread tendency to privilege the sensory models of our own time and place over those of others, and in contemporary culture this generally means favouring biomedical accounts. But the question arises: Should the neurobiologists necessarily have the last word on what counts as a faculty of perception? Might not each of the "alternative" perceptual paradigms we have been considering (Cashinahua, ancient Greek, medieval Christian, Scottish Enlightenment) have something to teach us about the sensorium? Indeed, it is only by approaching the study of perception with open senses and an open mind that we can arrive at a composite understanding of the changing *contexts of perception* that give the senses their meaning.

Overture II: Sensory Integration

The modern subdivision of the sensorium can be seen as leading to a finer appreciation of the biological substrate of perception. It is consistent with the modular conception of the sensorium that is otherwise reflected in the analytic orientation of most current research in the psychology of perception with its "sense-by-sense"—or, one sensory modality at a time—approach to the study of perceptual processes (even as the number of named senses has expanded beyond the canonical five). However, in recent decades, a more interactive, relational approach to the understanding of how the senses function has begun to take shape as a result of the growing body of evidence which points to the "multisensory organization" or "integration" of the brain.[11] As Gemma Calvert, Charles Spence and Barry E. Stein write in their introduction to *The Handbook of Multisensory Processes*:

> even those experiences that at first may appear to be modality-specific are most likely to have been influenced by activity in other sensory modalities, despite our lack of awareness of such interactions … [To] fully appreciate the processes underlying much of sensory perception, we must understand not only how information from each sensory modality is transduced and decoded along the pathways primarily devoted to that sense, but also how this information is modulated by what is going on in the other sensory pathways. (2004: xi–xii)

TABLE 0.1: A Measure of the Senses. "There are many opinions about how many senses we have" (adapted from the table in Durie 2005: 36).

SENSORY MODALITY	Conservative	Accepted	Radical
Vision	■	□	□
Light	□	■	■
Color	□	■	□
Red	□	□	■
Green	□	□	■
Blue	□	□	■
Hearing	■	■	■
Smell	■	■	□
2,000 or more receptor types	□	□	■
Taste	■	□	□
Sweet	□	■	■
Salt	□	■	■
Sour	□	■	■
Bitter	□	■	■
Umami	□	□	■
Touch	■	■	□
Light touch	□	□	■
Pressure	□	□	■
Pain	■	■	□
Cutaneous	□	□	■
Somatic	□	□	■
Visceral	□	□	■
Mechanoreception	■	□	□
Balance	■	■	□
Rotational acceleration	□	□	■
Linear acceleration	□	□	■
Proprioception—joint position	□	■	■
Kinaesthesia	□	■	□

SENSORY MODALITY	Conservative	Accepted	Radical
Muscle stretch—Golgi tendon organs	□	□	■
Muscle stretch—Muscle spindles	□	□	■
Temperature	■	□	□
Heat	□	■	■
Cold	□	■	■
Interocepters			
Blood pressure	■	■	□
Arterial blood pressure	□	□	■
Central venous blood pressure	□	□	■
Head blood temperature	□	□	■
Blood oxygen content	□	□	■
Cerebrospinal fluid pH	□	□	■
Plasma osmotic pressure (thirst?)	□	■	■
Artery-vein blood glucose difference (hunger?)	□	■	■
Lung inflation	□	■	■
Bladder stretch	□	□	■
Full stomach	□	□	■
TOTAL	10	21	33

Examples of such modulation include the well-documented fact that, in noisy surroundings, speakers can be understood more easily if they can be seen as well as heard. This finding is readily explicable in terms of the redundancy hypothesis of classic information theory: two pathways or "information channels" are better than one. However, the new multisensory psychology of perception probes deeper to explore the *relationships* among the component parts of a multisensory signal. For example, in the case of animal and human communication, redundant multisensory signals can be subclassified into those that produce responses in the receiver equivalent to the response to each unisensory component (and hence called *equivalent* or *additive*), and those where the overall response is enhanced—that is, greater than the response to the unisensory components (*superadditive*). Multisensory signals may also be made up of stimuli which convey different (i.e. nonredundant) information. In such cases, the relationship between the component parts may be one of *dominance* as in the ventriloquism effect, where the seen lip-movements of the dummy alter or "capture" the apparent location of the speech sounds.

A further, particularly intriguing pattern of intersensory relations is that of *emergence*, as exemplified by the McGurk effect. In the McGurk experiment, a research subject is shown a dubbed video of an actor's face pronouncing syllables. It would appear that the seen lip-movements can alter which phoneme is heard for a particular sound (e.g., a sound of /ba/ tends to be perceived as /da/ when it is coupled with a visual lip movement associated with /ga/). In this instance, the response to the multisensory signal is new, qualitatively different from the response to either of the unisensory components (see Figure I.1), and thus demonstrates *emergence*. It is a perception without any direct basis in sensation.

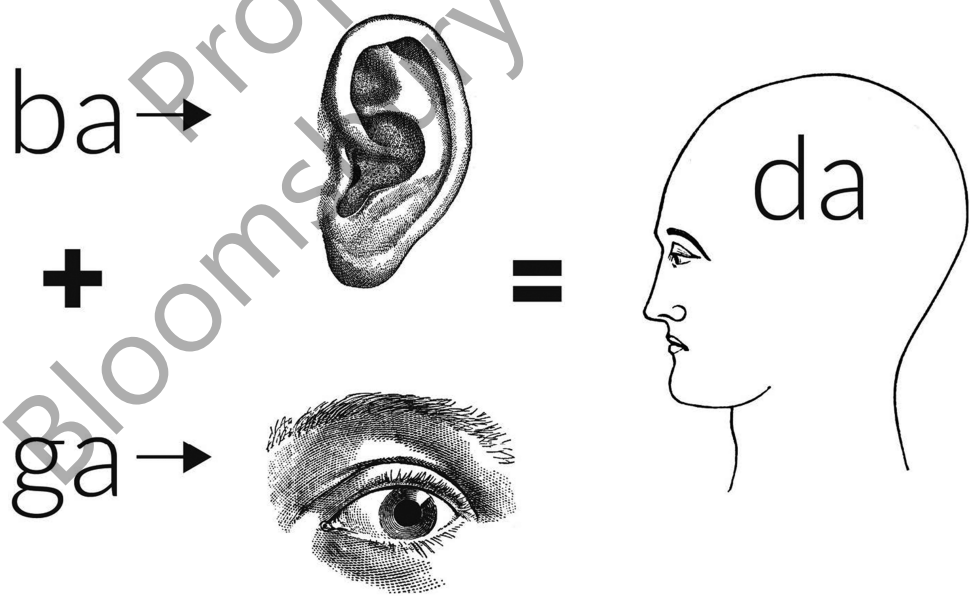

FIGURE 0.1: The McGurk Effect. Illustration by Shannon Leah Collis. The subject is shown a film of a person silently mouthing /ga/ /ga/ /ga/.The facial movements are synchronized with an audio track in which the person says /ba/ /ba/ /ba/. The person in the film is perceived to be saying /da/ /da/ /da/ by the subject. This experiment demonstrates the interactivity of the senses in perception.

Many of the studies in the *Handbook* use modern neuroimaging techniques to reveal the multiple sites of multisensory processing in the brain, including many regions long thought to be modality-specific or "primary sensory" areas as distinct from the so-called higher-order "associative areas" traditionally assumed to be responsible for the formation of unified percepts out of the diversity of inputs. In addition to demonstrating the functional *interdependence* of the modalities, a number of these studies point to the functional equivalence or *adaptability* of the modalities. For example, it is now clear that sensory-specific areas can be "recruited" or "remapped" by other sensory-specific areas in situations of sensory deprivation or intensive perceptual training. Thus, the visual cortex in blind individuals has been found to show activation in auditory tasks while the auditory cortex in deaf individuals can be activated by visual tasks (Röder and Rösler 2004; Sur 2004). Such evidence of adaptive processing, or "cross-modal plasticity," underscores the importance of adopting a relational approach to the study of the sensorium in place of assuming that the senses are structurally and functionally distinct.

Other studies in the *Handbook* explore such issues as whether the sensory integration involved in speech perception is fundamentally the same or different from other kinds of multisensory integration (the same); whether the senses are differentiated at birth and become coordinated through experience—the developmental integration hypothesis—or are relatively unified at birth and become differentiated through development—the developmental differentiation hypothesis; the answer is neither: the formation the formation of percepts in early development involves the joint action of developmental integration and differentiation processes); and, whether the phenomenon of synesthesia (i.e. the union or crossing of the senses) might not provide a better model for conceptualizing perceptual processes than the conventional sense-by-sense approach that has dominated research on the senses and sensations to date. More on the topic of synesthesia presently.

The *Handbook of Multisensory Processes* (now in its second edition) is a landmark text. But even though it is "revolutionary science" (Kuhn) as regards neuroscience, it remains "normal science" from a sensory studies perspective due to its failure to grapple with deep historical facts and its imperviousness to cross-cultural understandings of the sensorium. As regards the history of the senses, there is but one line in the *Handbook* that alludes to the complex history of sensation we have been tracing. The editors observe that "it is interesting to note that with the specialization of modern research and the tendency to focus on the functional properties of individual senses, an early perspective was set aside, namely, that perception is fundamentally a multisensory phenomenon" (Calvert et al. 2004: xi). They do not elaborate further. As regards the anthropology of the senses, there is again but one line (one line in 915 pages!): it is noted that the McGurk effect is significantly weaker in Japanese test subjects than in American test subjects (2004: ch. 13). Such restricted allusion to the senses in the expanded field (i.e. the senses in history and across cultures, rather than the laboratory) point to a serious lacuna in the presumed universality of the account of human perceptual processes presented in the *Handbook*.

At least one of the editors of the first edition was, however, sensitive to this issue—namely, Charles Spence, the Director of the Crossmodal Research Laboratory at Oxford University. With characteristic verve, he joined a team of researchers and travelled to Northern Namibia to investigate the question of cultural variations in crossmodal interactions. This team found that the Bouba-Kiki (shape–sound symbolism) effect held among the Himba of Namibia—that is, the Himba mapped a rounded shape (resembling a sack of potatoes) to the sound "bouba" and an angular shape (an irregular,

pointy star-like figure) to the sound "kiki," similarly to Europeans. This finding might be taken to suggest that this effect may be a perceptual universal. However, the team also found that

> in contrast to Westerners, the Himba did not map carbonation (in a sample of sparkling water) onto an angular (as opposed to rounded) shape. Furthermore, they also tended to match less bitter (i.e. milk) chocolate samples to angular rather than rounded shapes; the opposite mapping to that shown by Westerners. (Bremner et al. 2013: 165)

This experiment is noteworthy for its "double-crossing" protocol: crossing cultures and crossing modalities, and for its demonstration that "cultural-environmental as well as phylogenetic factors play a central role in shaping our repertoire of crossmodal correspondences."

To pick up on the other aspect of the lacuna at the heart of the *Handbook*—namely, the short shrift given to the long history of reflection on the interrelation of the senses, the preceding discussion has gone a considerable way toward correcting this occlusion. It is now time to turn our attention to the work of some more contemporary students of the senses. Consider "The Unity of the Senses," which is included here (3.1) by the early-twentieth-century musicologist Erich M. von Hornbostel. This essay is remarkable for its holism, as when he asserts that "there is a sensuous that is not limited to any single sense" (i.e. not a "private property of any one sense") and that there are "super-sensuous sense-perceptions" (e.g. "brightness" being predicated of sound as of colour). Von Hornbostel also canvassed and cited various cross-cultural evidence (limited though it was) in support of his claims (e.g. a certain African language "has a special word for 'see'; but only one general word for 'hear,' 'touch', 'smell', and 'taste'"). This essay recuperates the philosopher Aristotle's notion of the common sense, but with an empirical twist.

Another early example of a crossmodal approach to the study of perceptual processes is presented by psychologist Paul Rozin in "'Taste-Smell Confusions' and the Duality of the Olfactory Sense" (3.2.). Rozin makes the point that flavor perception is contingent on the blending of the senses of smell and taste and whether an olfactory stimulation is referred to the body (mouth) or the external world. This phenomenon is sometimes called "odor-taste synesthesia" and is actually the topic of one of the studies in the *Handbook*, as well. In their chapter, Richard Stevenson and Robert Boakes begin by noting that, perhaps because it is such a common effect, this variety of synesthesia has failed to attract much popular attention or scientific documentation. Yet the evidence is clear: "the majority of people appear to experience odor-taste synaesthesia. First, *sweet* is one of the most common descriptors applied to odors … [Furthermore,] when smelling an odor, most people can more easily recognize a taste-like quality such as sweetness than more specific qualities such as strawberry- or banana-likeness" (2004: 69). This finding raises the question: When we speak of the odor of vanilla or strawberry as "sweet" are we speaking in metaphor rather than reporting an actual olfactory sensation? Stevenson and Boakes answer this question in the negative—that is, they reject the "metaphor-explanation," as is typical of psychological researchers, in contrast to geographical researchers, such as Yi-Fu Tuan (1.24) and anthropological researchers (see Howes and Classen 3.22). The central argument of their chapter is physiological, namely:

> that, as a result of eating and drinking, patterns of retronasal odor stimulation co-occur with oral stimulation, notably of the taste receptors, so that a unitary percept is produced by a process of either within-event associative learning or by a simple encoding as one event. Eating sweet vanilla-flavor ice cream will ensure that the

> retronasal odor of vanilla becomes associated with sweetness; on some later occasion the smell of vanilla will seem sweet, even if no conscious recollection of eating ice cream comes to mind. (Stevenson and Boakes 2004: 81)

Stevenson and Boakes further assert that: "Odors display taste properties but do not elicit auditory or visual sensations" (2004: 73). Here, however, in rejecting the possibility of audio-olfactory or visuo-olfactory synesthesia out of hand, the authors overreach themselves, for this assertion can be questioned from an anthropological perspective. Counterexamples include the "golden smell" of ancient Egyptian lore (Goldsmith, personal communication) and the "green smell" known to certain Australian aborigine populations (Young 2005). Furthermore, it is common in various African languages to speak of "hearing a smell." Among the Dogon of Mali, for example, speech is understood to have "material properties that … are more than just sound … [It] has an 'odour'; sound and odour having vibration as their common origin, are so near to one another that the Dogon speak of 'hearing a smell'" and classify words as smelling either "sweet" or "rotten" accordingly (Calame-Griaule 1986: 320). This association between smell and sound is reflected in the way the Dogon will operate on the nose of young person (e.g. through piercing) in order to discipline and correct both their hearing and their speech. Hence, the Dogon *practice* audio-olfactory synesthesia despite the fact that there is no basis for this in human physiology, according to Stevenson and Boakes. This écart illustrates a point made by Sander Gilman in *Goethe's Touch*: "Our fantasies about the senses are in no way limited by the biological realities of the senses … We can (and do) attribute and associate with any given sense much that is beyond the innate capacity of that sense" (1988: 1–2). Where we differ from Gilman (who, being a literary scholar, is more attuned to fantasy or sensory fiction) is in questioning whether the "innate capacity" of a sense can be specified independently of the cultural context of its usage, and in our focus on sensory *practice*—the techniques of perception, or "ways of sensing." Sensory practices may seem fictional, but the fact that they have a performative dimension makes them actual.

Disciplines

In this concluding section of Part I (Foundations) and throughout Part II (Key Domains and Concepts), the contributions of the biology, psychology and neuroscience of perception to our understanding of the senses and sensation shall be canvassed. Of note: not all of the theorists whose work we shall be considering belong to any of these three fields. This is partly because sensory studies is an interdisciplinary field of inquiry, transcendent of the specific disciplines that flow into it, and partly because the orthogonal approach advocated here can help throw the specific contributions of each discipline into relief. Also of note: the following investigations are not confined to the biological senses but also incorporate the "extension" of the senses by means of different technologies. This is in keeping with McLuhan's position in *Understanding Media: The Extensions of Man* (see further Friesen 3.15). This expansive approach is also motivated by our concern to highlight the sociality of sensation and subjectivity of perception, which is for the most part lacking from the natural sciences.

Briefly, the biology of the senses brings out cross-species diversity in the perception of the environment, and thereby casts the limits of human senses into relief (e.g. humans lack the electric sense of eels, the magnetic sense of birds). The psychology of the senses focuses on the mental life of sensations. However, as we have seen, the assumption that perception goes on exclusively in the head is questionable and needs to be supplemented