The Individuation of the Senses

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How many senses do humans possess? Five external senses—sight, hearing, touch, smell, and taste—as most cultures have it? Should proprioception, kinaesthesia, thirst, and pain be included, under the rubric *bodily sense*? (Ritchie and Carruthers, this volume) What about the perception of time (Le Poidevin, this volume) and the sense of number? And what makes the traditional five senses unitary anyway? Why are colour perception and shape perception both included under vision? Aristotle discussed such questions in the *De Anima*. H. P. Grice (1967) revived them. More recently, they have taken on fresh interest as a result of a collection of essays edited by Fiona Macpherson (2011a).

Questions about counting the senses reduce to two more fundamental ones.

1. What kind of faculty counts as a sense?
2. By what principle do we distinguish the senses from one another?

This entry reviews some approaches to these questions. *Inter alia*, it advances two new ideas:

- The senses constitute a group of information gathering faculties within which content from each can be integrated with content from the others. This

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suggests a relational answer to question 1: the senses are different from other information-gathering faculties because together they form a system by virtue of the content-integrating relations they bear to one another.

- Broadly speaking, there are two approaches to distinguishing the senses. One (the “sensory” approach, as it will be called here) aligns more closely with how scientists tend to think about question 2. The other, introduced here as the “perceptual” conception, aligns, at least extensionally, with everyday, or “folk”, conceptions. In the “perceptual” conception, each modality is associated with a system of knowledge-gathering perceptual activities. These activities differentiate the modalities.

I. What Is It To Sense?

In order to count the senses, one must know not just how they are distinguished from one another, but also how they are differentiated as a group from other capacities. Minimally, a sense is a faculty that monitors the current state of its external and bodily environments in order to mediate an organism’s response to these environments. But this is not a sufficient characterization, for it includes too much.

The body monitors its environment for homeostatic regulation. For example, blood CO₂-level is monitored by dedicated chemoreceptors; the output of these receptors is used to regulate breathing. Let’s call such mechanisms HR monitors. Yet, HR monitors, such as the chemoreceptors just mentioned, are not included among the senses, as conceived either by the tradition or by scientists. Why are they excluded?

One commonly held intuition is that the senses provide the subject with content-bearing experience, while HR monitors do not. Thus, information about blood CO₂-level feeds directly into the body’s regulatory systems, and the subject

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2 I use the term “content” to characterize the representational output of the senses—what they “tell” us. Content is usefully defined as the set of circumstances in which the perceptual state bearing that content would be accurate. See Nanay (this volume).
does not directly experience them. Of course, you may come to believe that your blood CO$_2$-level is high when you feel yourself breathing harder, but this is only because you know something about how the body controls breathing. Without such experience, you cannot come to know your blood CO$_2$-level. The CO$_2$ monitor provide us with conscious access to its content.

Certain kinds of blindsight show a similar pattern. There are patients who, because of damage to a part of the visual system, lack conscious visual experience. But, because other parts of their visual system are intact, they are able to execute visually guided action. These patients can become adept at knowing certain aspects of their environment—for example, the shape of things they handle—simply by monitoring their own bodily responses (in this case, grip shape). (Goodale and Milner 2004 describe the everyday life of one of these patients, DF.) What most people recognize holistically, directly, and non-inferentially, these patients identify by learned associations with other bodily responses and sensory states. We can come to know our blood CO$_2$-levels in this second, but not in the first, way.

Because sensory experience is connected with the formation and assessment of beliefs, direct availability via experience leads to another important characteristic. You can “withhold assent” from putative information your senses provide: two lines might look equal, but you may refuse to believe that they are equal, because they are part of a Müller-Lyer diagram. But you cannot do the same with information provided by HR monitors. Subjects may, of course, voluntarily over-ride homeostatic breathing-control—for instance, they may deliberately breathe slowly and deeply after a run. When they do this, they are not contesting, or “withholding assent” from, the output of the CO$_2$ monitor. Having no access to this output, they exercise direct control of breathing independently of it.

The senses do not control belief, then. Rather, they provide consciously available “perceptual content”, which the subject uses, with due attention to other aspects of her situation, as a reason for belief. By contrast, homeostatic systems directly influence the body’s reaction. They do not merely provide the organism
with defeasible reasons for belief, which in turn is a condition for bodily control. This suggests:

*Subjective Experience Criterion* A sense is an information-gathering faculty that provides a subject with informative experience that rationally bears on her beliefs, but from which she can withhold assent.

Though initially plausible, this characterization of the senses faces serious difficulties.

1. With regard to “withholding assent,” many philosophers hold, and there is good empirical reason to believe, that in humans, sensory appearance creates a *causal* disposition to believe. When evidence opposes the belief, the causal pressure can be overridden, but it still exists. So the case is structurally similar to the detection of elevated blood CO$_2$-level. Both systems seem to create causal pressure to do something—to breathe more quickly or to form a belief. This causal pressure cannot be denied in either case, but the effect can deliberately be overridden in both. Subjects don’t neutralize the belief-creating force of sensory content; rather, they defeat the formation of belief.

2. With regard to content-bearing conscious experience, there may be unconscious perception. (Prinz, this volume.) Moreover, signal detection theory (Winer and Snodgrass, this volume) suggests that whether perceptual content is conscious, and whether it serves as a reason often depends not just on its own nature, but also on perceiver “bias”. Thus, consciousness and aptness for reasoning are not intrinsic characteristics

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3 The point is generally made in the context of action. William James wrote: “We may lay it down for certain that every representation of a movement awakens in some degree the actual movement which is its object” (1890, 526). Generally speaking, acting contrary to an impulse is a matter of suppressing it, not of blocking its formation. For a review of “inhibitory control,” see Munakata et al, (2011). This pattern extends to epistemic assessment, where response is slowed by the need to suppress unwanted causal influence. For a recent example of evidence of this, see Kovács, Téglás, and Endress (2010).
of perceptual content and cannot serve as unequivocal markers of the senses.

3. With regard to the distinction between HR-monitors and sensory systems, lower animals such as honeybees and ants have sensory systems (Keeley, this volume), but they lack rationality and perhaps even consciousness. Certainly, they do not treat sensory content as reasons for belief. So one might think that in these animals, the proposed mark of the senses breaks down.

One way to address these concerns is to lean more heavily on the idea of situation-dependent response—the idea that in some situations, sensory content, blue, will have one kind of response, and in others, another—putting aside considerations of rationality and consciousness of sensory output. Overemphasis of these characteristics of response-modulation is anthropocentric, it might be said: it seizes upon a human way of doing what many other kinds of animals do in different ways.

Here is one model. The senses (as well as the emotions, etc.) post their output to a temporary store called “working memory” where it is held for a short period. Various action-controlling and cognitive systems, including belief-formation systems, have access to content in working memory, and use it in conjunction with other information, including motivational and stored content. (Baars 1997 calls this temporary store the “global workspace.”) Response to a sensory state depends on the other contents of working memory: for example, if prior associations or memories available to working memory incline a subject to treat a particular object as green, sensory content that it is blue may be overridden.

I started by noting that the senses enable an organism to respond appropriately to the current state of its external and bodily environments. I now add that the “traditional senses” do so in the context of the organism’s goals and, importantly, in the light of other sensory information that feeds into working memory. The effect of the senses is, in other words, indirect. Sensory output is held
in abeyance, so to speak, awaiting other information that might defeat it. In humans, the senses often work through consciousness and rationality. By consciously experiencing something as blue, I gain rational support for the belief that it is blue, but whether I actually believe that it is blue depends on other information, including other sensory information.

In lower animals, the assessment of sensory content is performed differently. A honeybee sips from flowers that bear one coloured pattern but not from those that bear another; its action is visually guided. But we have no idea whether it performs this act of discrimination by anything involving conscious awareness; certainly, it does not utilize the norms of rational assessment. Nonetheless, the bee’s action is also dependent on its goals and other information: the bee may detect a lurking predator and veer off in another direction, or it may be time to return to the hive, and so it may abstain. Thus, the bee’s visual system cannot be said to control action directly: it too posts output to a “workspace” where it interacts with other content.

A second important mark that sets the senses off from other information-gathering faculties, including HR monitors, is that they are the basis for learning. Consider, in particular, associative learning or conditioning. A response to a stimulus $P$ can be transferred to a sensed stimulus, $Q$, because $Q$ has been sensed together with $P$.

- Suppose that Suzy habitually makes coffee while she prepares breakfast. Her body comes to associate the smell of coffee with food to come. One day, she makes coffee, but decides to skip breakfast. Nevertheless, her stomach growls at the smell of coffee. Her instinctive (or unconditioned) response to food has spread, by associative learning, from the food itself to the smell of coffee, because

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4 Two important notes: (a) It is not necessary that both $P$ and $Q$ be sensed (though they are in Pavlov’s 1927 experiments). The conditioned stimulus $Q$ needs to be sensed; the unconditioned stimulus need not be. On this point, see Dworkin and Dworkin (1995). (b) Gallistel and King (2010) argue that the transference of response model of associative learning cannot capture its complexities, and that a more computational model is required.
the smell of coffee is a learned (or conditioned) indication of food to come.

Information-capture for regulatory purposes does not feed into conditioning in this way.

- Suppose that Barbara habitually undertakes a Vikram Yoga exercise (performed in a hot room) that increases her blood pressure and makes her sweat. Performing yoga is a reliable indicator of heat. One day, she shows a friend her yoga exercise, but does so in the cold outdoors. Her blood pressure rises, but she does not sweat. Though the yoga exercise and the elevated blood pressure are indicators of heat, they do not become triggers for the mechanisms that help her body adjust to heat. Associative learning does not occur.

Organisms respond to the current environment in many different ways. One is *sensory anticipation*. A sensory signal can come to be treated as a sign of something to come, and may prompt an efferent system to take action that anticipates a *future contingency*. More importantly, organisms *learn* from the senses.

Learning occurs both within and across the senses. In short, the senses are integrated into a *learning system*. HR monitors do not participate in this system. Their triggering function cannot be linked to any other signal. So, unless an autonomous bodily response has a *sensory* trigger, it simply has to wait for the HR monitor to activate it. To summarize, the senses trigger conditioned, as well as unconditioned responses; HR monitors trigger only unconditioned responses.5

In virtue of the above considerations, I now propose:

*Integrated System Criterion* There is a certain group of information-gathering faculties that together form a system within which goals,
actions, beliefs, and learning are modulated by content provided by all
the information-gathering faculties in the group, and do not depend
on any one taken by itself. The information-gathering faculties in this
group are the senses.

The Integrated System Criterion is relational. It concerns how sensory
information can be used to anticipate unsensed things. Non-sensory information is
excluded from these integrative connections. The thrust of the Criterion is that the
senses have nothing intrinsic in common that distinguishes them from other
information-gathering faculties—except that which is necessary for their output to
be integrated in working memory and associative learning, and that which follows
from such mutual integration.

The conditions proposed thus far are not yet sufficient. The “number sense”
by which primates estimate the numerosity of (sufficiently small) collections
(Gelman and Gallistel 1978, Carey 2009) seems to satisfy the above criteria—it
contributes to working memory and associative learning, and seems to provide
direct awareness of number.

But it is not a sense modality. The reason is quite simple. Input to perceptual
systems comes from transducers—cells that convert incident energy into a neural
pulse that carries information about this energy. (For example, the rod cells of the
eye convert light into neural pulses that carry information about this light.) Sensory
transducers respond to the environment in physically determined ways: for
instance, the basilar membrane in the ear is so constructed that different parts
resonate, as a matter of physical law, to different auditory frequencies. The number
sense lacks transducers. It operates equally well in different modalities—we can
quickly estimate the number both of small collections of successive light flashes and
of successive sounds (though possibly not of tactile stimuli—see Gallace, Tan, and
Spence 2008). Collections of objects and events do not act on cells that emit a neural
pulse that carries information about number. Rather, the number sense operates on
the outputs of (some) other senses. It is thus a post-perceptual module, rather than a sense modality.

A further complication is that in a genuine sense modality, the neural signal emitted by sensory transducers is, as Brian Keeley (2002) points out, processed in ways that are “historically” (i.e., evolutionarily) dedicated to the recovery of information about external stimuli. Keeley notes that the weak electric current from a charged 9V battery creates a definite sensation on the human tongue. This is because touch and taste receptors respond to the electric current that the batteries emit. However, humans lack information-processing data-streams designed by natural selection to extract informational content about and respond to ambient electricity from this stimulation of touch receptors. Consequently, the sensation produced by a weak current feels like a tactile stimulus on the tongue, or sometimes like a flavour, not like an event of a distinct sensory type. By contrast, electric fish have systems dedicated to processing information about electrical fields, and they perceive quite specific features of these fields. Sharks, for example, detect prey by the disturbances in the electric field caused by their movement (Hughes 1999). So though both humans and sharks sense electric current, sharks (but not humans) have a distinct sense modality for electric fields or currents.

These ideas are important in determining whether pain and sexual arousal are sensory states; both were posited as such by some historical authors (Dallenbach 1939) on the grounds that each is associated with a special kind of experience or quale, which is, moreover, informative about current circumstances. In the historical debate about pain, subjective experience proved inconclusive. Is the pain of being burned a particularly intense, and hence unpleasant, sensation of heat? Or is it a distinct sensation that accompanies intense sensations of heat? Introspection does not decide the question.

The transducer/processor condition throws some light on the issue. Some pain relies on receptors activated by high threshold values of mechanical, thermal, and chemical stimuli, and processed by a dedicated system in the brain (Craig 2002,
2009). One might hold that these kinds of pain are sensory, and assuming that there are dedicated data-streams for them, it may be appropriate to treat of them as constituting a single sense. (The same can be said, for instance, of thirst: it has dedicated transducers known as osmoreceptors and a dedicated computational system [McKinley and Johnson 2004].) These pains do not belong in the same modality as the intense stimuli that are associated with them—sensations of warmth etc. They are separate and are produced by a distinct system. On the other hand, certain sensations are painful just because they are very intense—loud noises and bright lights, for example. Here it is appropriate to say that an auditory sensation is made painful by its intensity. There is no separate sensation of pain here. In sum, some painful sensations are the products of a separate sense, while others are not.

Sexual arousal is different from pain and thirst. First, it should be noted that sexual readiness, or arousal, arises in a context-sensitive way from other perceptions, some visual, some tactile, etc. Arousal is the state of the body that enables sexual performance. Now, there may well be processes that detect some of the bodily changes that constitute sexual arousal. This may account for the characteristic feel of excitement associated with arousal. But this feeling of excitement should be distinguished from arousal itself. The feeling could be regarded as awareness of arousal—assuming that the conditions discussed above are met. Or it could be said to be a concomitant of arousal. Both options are different from saying that arousal is itself a perceptual state.6

The above considerations reveal two important aspects of the senses. They are subject, first, to an

Source Condition A sense depends on transducers and information processing systems dedicated to information-capture regarding specific qualities of the impinging stimulus.

6 Louise Richardson asks (in correspondence) whether the motivational import of sexual excitement disqualifies it from being sensory—the same question could be asked about pain. In my view, perceptions always have a motivational aspect: at the very least, they provide motivation for forming a belief. So no.
Secondly, they are subject to an *Output Condition*—namely, the Integrated System Criterion formulated above: that is, they modulate each other with respect to the beliefs and actions that flow from their operations.

*Sense Definition* A sense is an information-gathering faculty that is subject to the Source Condition and Integrated System Criterion above.

These conditions throw light on some difficult cases. One, discussed by Keeley (2002) is vomeronasal sex detection (VSD). Humans apparently possess nasal receptors for pheromones: these enable them reliably to detect the sex of another human simply by sniffing their breath. (This is empirically disputed—see Meredith 2001—and my treatment is hypothetical.) Keeley classifies VSD as a perceptual system on the strength of the input condition alone. But one important point to consider is that most subjects are unaware that they are sensitive to sex in this way: the pheromonally mediated response is not, as far as we know, modulated by the other senses. (For example, the fact that a woman is disguised as a man will not slow or suppress the VSD response.) And there is no documented way that this information can assist in learning: you cannot, as far as anybody knows, associate (for example) an auditory signal with the pheromones detected by VSD. It is possible, therefore, that VSD operates autonomically; perhaps, it simply prepares the subject for the presence of a potential sexual partner. If so, it fails the Use (i.e., the Integrated System) Condition, and would not count as a sense.

The sense of time is more difficult to judge. We possess a number of “endogenous oscillators” (Gallistel 1990) that govern bodily processes of different periodicities ranging from menstrual and circadian rhythms, down to the very short time periods involved in conditioning and the timing of our limbs while walking. The standard view is that these timing processes work by averaging the periods of the oscillators (since these are not precisely synchronous), and are thus “emergent properties of neural dynamics” (Wittman and van Wassenhove 2009). Should the endogenous oscillators be regarded as transducers for a sense of time? That is, do periods of time *cause* them to emit a pulse that carries information about these
periods of time? Both sides of the question can be argued. One might argue that time is immaterial and therefore never a cause. Such a position would be a reason to exclude the sense of time: the oscillators are not causally influenced by time as such. This might lead one to say that what we experience as the passage of time is actually the periodicity of certain bodily processes, which stand proxy for the passage of time. As opposed to this, one might argue that the important point here is that the oscillators function as a proxy for time in much the same way as the retinal image is the proximate substitute for distal occurrences. These questions cannot be decided here.

A methodological remark will serve as a transition to the next section. Matthew Nudds (2004) has argued that *SENSE* is an intuitive concept that we employ for certain everyday purposes. This sort of concept does not have objective scientific content, Nudds suggests; it relies simply on societal agreement, or “convention”. He rejects questions about such things as vomeronasal sex detection because “our conventions may have nothing to say about such cases.” This suggests that Nudds thinks of *SENSE* as *extensionally* defined. We know that the traditional five senses are senses because we have agreed to treat them as such, and not because we have an abstract idea under which these fall.

I am proposing, by contrast, that *SENSE* is *intensionally* defined. It is not simply given to us in intuition that there are five external senses or that pain is or is not a sense. Rather, a certain concept of *SENSE* is given to us in intuition, and refined by science. Whether each of the traditional five senses falls under this concept depends on the facts about these—as we saw, pain turns out to be more diverse than intuition might have imagined. In principle, even vision could turn out this way (though, of course, there is no reason to think that this is going to happen). Other positions are possible. There may be an *ur*-concept that folk-psychology and science develop differently. Or there may be several different but overlapping concepts. Something might figure as a sense on some of these but not others (Macpherson 2011b). Alternatively, the choice among divergent concepts could depend on the explanatory or conversational context.
II. Distinguishing the Sensory Modalities

We turn now to the question of how to distinguish the senses. When does a group of perceptual processes count as belonging to a single sense modality? Philosophical approaches to this question generally appeal to one of two types of consideration—those immediately accessible to the perceiver and those based on the nature of things—the nature of the perceptual system, or of the kind of energy it detects, etc.—which the perceiver may not immediately know. (Some of them are recently discovered; some are clearly the state of science, but still possibly reversible.)

In the literature, one perceiver-accessible criterion is paramount—the “special introspective character” of experiences characteristic of a particular sense. The view is that vision is the sensory faculty that produces qualia that have the special introspective character of vision; audition those of audition, and so on. (Of course, visual qualia may be different in kind from one another: blue from red, for instance. The idea is that they are nonetheless marked by a higher commonality characteristic of vision.) H. P. Grice (1967), who holds a special place in the literature for reviving interest in the question of how to individuate the senses, is famous for arguing that the Special Introspective Character Criterion (SICC) is ineliminable. Grice tried to show that all other criteria either lean on it or are insufficient without it.

Now, in the previous section, we encountered considerations that throw SICC into doubt. First, the honeybee—though we attribute vision to it, we do not know whether it has conscious visual experience at all, and if it does, whether this experience is anything at all like ours (cf. Heil 1983).7 Secondly, the criterion is impossible to apply to certain cases. For instance, SICC does not help us decide whether the pain is a separate modality. If pain is a single modality, the painful experience of touching a hot stove belongs to the same modality as that of eating a very hot chilli, and thus to a different modality from the neutral sensation of heat that one experiences in a tepid bath. If, on the other hand, pain is simply a

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7 This difficulty would be ameliorated by the homology criterion, discussed in section IV—but this criterion is not perceiver-accessible.
characteristic of other experiences (for example, that they are uncomfortably intense), then these two kinds of pain belong apart; one is tactile, the other gustatory. The quality of the experience does not seem to decide between these two accounts. Finally, there are information-rich experiences on which SICC delivers no verdict at all. Is sexual arousal a sensory state? If so, does it, or does it not, belong to the same modality as hunger? Is there perception of temporal passage separate from the perception of certain periodic bodily processes? SICC seems simply to be the wrong place to look for an answer to these questions. (It doesn’t seem, either, that we have an “everyday conception of the senses,” as invoked by Louise Richardson 2013, that would settle this issue about pain.)

At this point, a philosopher might suspect that a world-based (as opposed to experience-based) criterion might be useful. This was Aristotle’s approach. Aristotle explored two criteria of differentiation between senses. The first, which he considered ontologically prior, concerns the special properties that each sense directly reveals as vision reveals colour, audition pitch and sound volume, etc. Let’s call this the Special Properties Criterion (SPC). On the plausible assumption that we know what properties are presented to us in perception, this is a perceiver-accessible criterion.

There are two versions of SPC. In Hume’s version, each sense is characterized by any of the properties of which it provides direct perception. As Grice pointed out, Hume’s version falls to the problem of common sensibles—qualities, such as shape, which are sensed in more than one modality. But Hume actually discounts this problem, for he believed (following Locke) that visual shape is different from tactile shape (with the consequence that there are no common sensibles). But Gareth Evans (1985) convincingly argues that this is wrong: since shape is a geometrical property, its defining characteristics are not defined by how they are sensed. Thus, Hume’s way with shape is inadmissible. He does have another defence: namely, that visual shape is perceived indirectly, through colour. (“If we see it, it is colour.”) But this defence too is contentious. For in a display like the Kanisza triangle (below), the sensory detection of shape precedes that of colour.
Here, the visual system falsely detects a triangular contour in the foreground, which it then highlights by filling it in with a bright appearance. (In fact, the colour of the illusory triangle is the same as that of the background.)

Aristotle’s version of SPC is more cautious. It is that for each sense modality there is some property that is (a) directly perceived only in that modality, and (b) accompanies all perceptions in that modality. For vision, the distinctive property would be colour (or possibly brightness): everything that is visually perceived is perceived in colour. Audition has more than one such distinctive property: pitch and volume. Nudds (2004) argues that (b) is wrong. Anne Treisman and colleagues showed in the 1980s that colour is processed separately from shape and seem to be perceived together only because they are “bound” together when a subject directs visual attention to some part of her visual field (Triesman and Gelade 1996). Thus, shape might be sensed independently of colour. The same sort of thing could well be true of the other modalities as well. Aristotle’s version of SPC falls afoul, then, of the separateness of perceptual processes that fall under the same modality, though it could perhaps be modified to meet this objection.

There is another consideration—generalized from an argument in Grice—that cuts decisively against both versions of the Special Properties Criterion. Properties cannot by themselves define boundaries between the senses. What makes colour a distinctively visual property? Surely the answer cannot lie in the intrinsic nature of colour; it has something to do with the relation colour bears to the senses. Perhaps the crucial fact is that information concerning colour reaches us through light and the visual transducers; perhaps it is that our experience of colour
is distinctively visual. Either way, SPC is necessarily either incomplete or circular: it must lean on some other differentiating feature of the senses.

It is worth noting that SPC and SICC actually cut against each other. Consider the McGurk effect. When you listen as well as watch somebody uttering the syllables /ga/, /ga/, ga/, you may well feel that the look of the mouth is completely discrete and different from the sound of the phoneme: one is a bodily movement revealed by looking; the other is a sound that you hear. But McGurk and McDonald (1976) performed the interesting experiment of filming a speaker saying /ga/, /ga/, ga/, and substituting an audio track of the sound /ba/, /ba/, /ba/ (synchronized with the lip movements). Upon watching this mismatched audio-visual clip, subjects automatically and irresistibly hear /da/, /da/, /da/, a phoneme intermediate (in terms of articulation) between the visually presented /ga/ and the auditorily presented /ba/. In this experiment, subjects appear to hear /da/: thus, on SICC, phonemes are perceived by the auditory sense. However, the McGurk effect shows that vision contributes to the special introspective character of phonemes—thus indicating that this introspective character is not unique to audition (or speech perception).

A further point regarding the McGurk effect is that when subjects look and listen to a speaker they are much faster and make far fewer errors of identification than when each modality is unassisted by the other. This shows that the two modalities act together in this domain (Green and Kuhl 1991, Jones and Munhall 1997). Phonemes are actually perceived by the operation of two kinds of perceptual process, visual and auditory. This seems to indicate that the detection of phonemes is multisensory; they are not, as shape is, merely perceived by two different modalities taken singly. This puts further pressure on SPC, which in Hume’s version doesn’t allow for shared properties, and even on Aristotle’s version does not consider the possibility of two modalities cooperating.

Aristotle’s second world-based criterion is the medium through which received information is transmitted: in the case of vision, he says, this is “the
transparent”; for audition, the compressible; for touch, flesh; for gustation, saliva; and for smell, something “analogous to the transparent” (presumably an odourless medium capable of transmitting odour). Putting Aristotle’s outmoded science aside, this is a promising approach. Earlier, we saw that the input end of each sense modality is a set of transducers that convert ambient energy into a neural pulse. Different forms of energy require different transducers, and this may provide us not only the evolutionary reason why there are different senses—environmental information is available in more than one form of energy—but also the basis for differentiating them. Why do we have both vision and audition? Because both light (the sub-spectrum of electromagnetic radiation that is of the right wavelength to be reflected by atoms) and sonic energy (compression waves in air or water) carry information. Why are vision and audition different? Because the same transducers will not work for both—transducers are specialized for the type of energy incident upon them.

This suggests a Hybrid Medium-Transducer Criterion (HMTC): a sense is a collection of perceptual processes that begin from transducers specialized for information capture from a particular kind of energy. HMTC does not demand one type of transducer for each sense: rather, it groups transducers by their receptivity to the same kind of energy. Thus, vision has rod and cone cells, but both are sensitive to light. Similarly, touch has several kinds of receptors sensitive to mechanical energy. This criterion is inaccessible to the perceiver; it is world-based and scientifically determined. It is, however, perceiver-involving in that transducers are components of the perceiver’s sensory apparatus.

One reason to group such perceptual processes together is that they will be separate and independent in their earlier stages. The early stages of auditory processes are concerned with extracting environmental information from sound; they will be discrete from the early stages of visual processes because the principles of extracting information from sound are different from those of getting information from light. This consideration is quite general: extracting information from one medium is different in principle from extracting it from another. (See, however,
Kiverstein, Clark, and Farina on sensory substitution in this volume—particularly, on the “meta-modal brain” concept.)

HMTC captures quite well how scientists think about modality and multisensory perception. The early stages of sensory processing are about extracting properties of the signal received by the transducers. At these stages, processing is discrete. The later stages are concerned with the sources of the signal—i.e., the distal environmental objects that emit the signals received by the transducers. Since all modalities are ultimately concerned with the same (or at least with overlapping) environmental objects, the information extracted by other perceptual processes becomes relevant. Thus in the late stages of sensory processing, the separate early data-streams flow together. This is well illustrated by the McGurk effect, where visual and auditory data are reconciled in order to get the best possible conclusion about the speaker’s utterances. Because HMTC is primarily concerned with a distinction between sensory data streams in their early stages, it is appropriate to entitle it a sensory criterion, and the modalities distinguishes sensory modalities. Later, I shall introduce a partially overlapping notion of perceptual modalities.

HMTC runs into perplexities, however, with touch and gustation. Touch has as many as six kinds of transducer: mechanoreceptors for pressure, weight, and stretching, thermoreceptors, chemoreceptors, pain and itch receptors, and (possibly) receptors specialized for gentle stroking. These are the “cutaneous” receptors (McGlone and Spence 2010). In addition, there are motion receptors embedded in the muscles and joints. Accordingly, some suggest that touch is multisensory (Lederman and Klatzky 2009). Moreover, there is a difference between active and passive touch (Gibson 1962). In active touch, which includes haptic exploration of objects (and thus employs bodily activity), one perceives the properties of external objects—shape, size, texture, temperature, etc. In momentary passive touch, one perceives the condition of one’s own body. (Temporally extended passive touch is intermediate: one can sense certain properties of external things when they are impressed upon or moved against the skin.) By the Special
Properties Criterion, therefore, active and (momentary) passive touch are different modalities.\(^8\) Despite these complications, most people think of touch as a single modality. (Fulkerson 2011, forthcoming has one account of why it should be so considered.)

Flavour perception is even more complicated. Put a chocolate mint in your mouth, and you experience it as sweet, characteristically chocolatey, and cool. You probably feel little hesitation identifying these properties as delivered by a single modality (Richardson 2013). In fact, you would probably say that the confection has a single, complex flavour in which the above are experienced as components. That is, the sweetness and the chocolatiness are not separate, as are the colour and the sound of a barking dog—they are merged together within a single complex whole. And it seems as if this complex property is the *taste*—or rather, to anticipate the next paragraph, the *flavour*—of the mint.

How these components of flavour come together is philosophically quite puzzling (Auvray and Spence 2008). The sweetness of the confection is detected by *taste proper*, which involves transducers on the tongue—sweet, sour, bitter, salty (and maybe umami and fat) are the qualities that come out of this set of transducers.\(^9\) Chocolate is detected by retronasal olfaction—that is, by vapours from the mouth rising into the nasal cavity and passing over olfactory transducers. (This is called “retronasal” because the vapours pass over these transducers in the direction opposite to that when one sniffs something through the nostrils. The latter is known as orthonasal olfaction.) Interestingly, odours detected by sniffing are “referred to” (i.e., sensed as located in) something external—the smell is experienced as emanating from the thing in front of the nose—while the properties

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\(^8\) Michael Martin (1992) claims that one’s awareness of something one touches and the sensation of touching it are “simply one state of mind, which can be attended to in different ways” (204). The distinction between active and momentary passive touch argues against this; active exploration brings haptic awareness of things outside the body. There is, in fact, a perceptual deficit, astereognosia, in which patients are unable to feel the properties of external things, except through the sensation of being touched (as well as grip size etc.) Martin would have to say that this is a deficit of attention, which it almost certainly is not.

\(^9\) Incidentally, taste cells are found in the stomach and gut. It’s not clear what they do there, but they probably do not function as sensory transducers.
detected by retronasal olfaction are referred to what is in the mouth, and are sensed as gustatory qualities. That the chocolate component of flavour is experienced as located in the chocolate (rather than in the nose) is (at least partially) the contribution of touch. Finally, the coolness of the mint is sensed by the trigeminal nerve, an important part of the tactile and pain system in the face. Because of the extra-taste components, the complex quality attributed to the chocolate mint is called *flavour*, not taste. (See Spence, Smith, and Auvray, forthcoming, for a systematic effort to straighten out this terminology.) Even more so than touch and phonetic perception, *flavour* is genuinely multisensory, at least when viewed through the HMTC lens—here it is not just that touch, smell, and taste cooperate to identify flavours; it is that flavour experiences have components contributed by touch, smell, and taste.

From the point of view of HMTC, touch and *flavour* are multisensory. Consequently, most scientists show little hesitation in rejecting the intuitive view that they are single modalities (Smith forthcoming). This surprises most non-scientists: there is a strong folk-psychological intuition that *flavour* is delivered by a single modality, as are tactile properties. This disagreement is not about the facts relevant to the application of the transducer criterion—the ordinary person does not contest scientific theories regarding how many kinds of transducers are involved in *flavour* perception. It appears, therefore, that “the folk” employ a different criterion. In the next section, I try to figure out what this is.

**III. Perceptual Modalities**

There is a perceiver-accessible criterion that may be of use here, namely that of a *perceptual activity*. Such a criterion is hinted at by Grice, who talks not only about seeing and feeling (perceptual experiences) but also about looking and touching (things that one does in order to perceive). Thus, he denies that pain is a sense in part because “there is no standard procedure for getting a pain”, i.e., no analogue of

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10 Murphy, Cain, and Bartoshuk 1977 describe this as a “confusion” of smell and taste. If smell and taste are taken as components of *flavour*, this is wrong, since the location of the flavour is correctly attributed to the food.
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an activity that stands to the experience of pain as “inhaling” (I would prefer to say “sniffing”) does to the experience of smelling, and looking does to seeing. (As will emerge, I do not quite agree with Grice about pain.) He seems to suggest, in other words, that sense is defined not just by an experience, but also by “procedures” for bringing about sensory experience. Now, it is likely that the kind of “procedure” that Grice had in mind was simply something like opening one’s eyes or unblocking one’s ears and thereby opening oneself up to visual or auditory experience—his point (with which I disagree) is that there is no analogous act of opening oneself up to pain. I want to follow up on Grice’s suggestion, but with a more expansive conception of “procedure”.

Perception is not merely a matter of sensory experience; it is a matter of actively examining the world. One tastes something by putting it into one’s mouth, chewing, savouring, attending to the components of flavour, etc. One visually examines things by looking at it from different angles and in different conditions of illumination, turning it over in one’s hands, bringing it closer to one’s eyes, etc. One listens to somebody by getting closer, cupping one’s ears, turning one’s head; one locates a sound or a smell by moving around and trying to get closer to its apparent location. One finds out the shape of something by touching and looking at it, and by manipulating it in one’s hands if it is small enough, or moving around it if not. These are examples of inter-connected purposeful activities that one uses perceptually to interrogate one’s surroundings. Let us call them modes of sensory exploration (Matthen forthcoming).

Sensory exploration is extremely important with regard to the externalization of perceptual content. In a momentary tactile event, if the subject is passive, she feels an event on her skin. If she actively explores something by moving her hand across it (etc.), she becomes aware of the thing’s properties (Gibson 1962). In flavour perception, retronasal sensation is referred to food in the mouth: for example, if a little whiff of lemon is sprayed into the nasal cavity from a tube placed in the mouth, then food that is in the mouth will taste lemony. As remarked before, touch has something to do with this—active touch, that is. Similarly, as Susanna
Siegel (2006) has observed, visually perceiving something as external is intimately connected with the awareness that the thing looks different when viewed at different angles—thus, the externality of visual content is tied up with one’s own motions when visually examining it.

Pain is another example. Though philosophers such as Grice and Aydede (2009) treat pain simply as an experience, active exploration—stroking, prodding, palpating, etc.—endow it with objective features such as quality (burning, itching, throbbing, etc), intensity, and location (“It’s deep in my elbow, not low on my forearm as I initially thought”). When one has actively explored pain, one becomes aware of a disturbance in the body and the sensory properties of this entity. (Aydede does not notice that one can be mistaken about the objects of active pain perception.)

Let us say that:

Two types of perceptual activity $A$ and $A^*$ are mutually certifying for property $F$ if there is a way to use each to check up on and change the credibility of the other with regard to $F$.

Touching an object and looking at it are mutually certifying for shape because by looking, one can increase or decrease the credibility of determining by touch that something has such and such shape, and vice versa.

Let us say further that:

A set of activity-types $S$ is a perceptual system if every member of $S$ certifies every other for all properties detected by each.

Looking at and touching an object are mutually certifying for shape, but they are nonetheless not members of the same perceptual system because there are properties detected by each that cannot be certified by the other—colour and weight are examples. However, looking at an object while turning it over in your hands and looking at it in different conditions of illumination (for instance, by taking it over to brighter light by the window) are members of a system, because they
mutually certify each other for colour, texture, shape, and every other property that either one detects. (Note that perceptual systems cannot overlap on this conception. For if activity $A$ belonged to systems $S$ and $S^*$, then every activity in those two systems would have to reinforce $A$ with respect to every property $A$ detects. But this would mean that there is only one system here, not two. 11)

With the idea of a perceptual system in hand, we define a *perceptual* modality as follows:

*The Perceptual System Criterion (PSC)* A perceptual modality is a faculty that gathers environmental information by means of a perceptual system. Two perceptual modalities are different if their perceptual systems are different.

Let us look at flavour perception from this point of view. We saw earlier that viewed from the perspective of the transducer criterion (HTMC) it is multisensory. In other words, it is not a single *sensory* modality. From the Perceptual System perspective, however, it is single. It is one *perceptual* modality. What does one do when one puts something in one’s mouth? One chews, savours, moves it around, swallows, etc. These activities engage different transducers, and scientists are therefore inclined to say that flavour is multisensory. However, these activities constitute a system: each mutually certifies the others with regard to *flavour*.

Applying PSC to flavour perception shows how it is at cross-purposes with HTMC, the hybrid transducer-medium criterion. PSC and HTMC play different roles in our thinking about the senses. HTMC is concerned with the different sources of information, the independent early stages of perceptual processing, and the merging of sensory information in later stages of perceptual processes. From the transducer perspective, flavour perception is not a single modality. PSC, on the other hand,

11 Matt Fulkerson observes that probing, stroking, palpating and the like are shared by active touch and active pain perception. His remark reveals something about the individuation of perceptual activities, for in the first case these are directed to an unchanging external object, whereas the latter seeks to modify pain sensation in a controlled manner.
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offers an account of how agents perceptually explore their environments. PSC is more concordant with our intuitions because it appeals to perceiver-accessible factors. These criteria define different conceptions of how to differentiate the senses. I have acknowledged this by saying that PSC individuates perceptual modalities, and one could say that the transducer criterion (HMTC) is concerned with sensory modalities. This terminology is meant to acknowledge that there may be more than one way to look at modalities; it oversimplifies the matter to say simply that PSC is correct and HMTC mistaken (or vice versa).

Barry Smith (forthcoming) writes:

[One] approach is to ask whether there is a single flavor sense, over and above its component senses. This approach treats the sense of flavour as a perceptual system that guides successful food selection by picking out flavours as multi-dimensional properties of things in our environment.

Smith implicitly suggests that there might be two ways of individuating the senses. I am suggesting that one of these looks to the carriers and recipients of information—transducers and media, the other is a “perceptual system.” My suggestion is that perceptual systems are unified by the perceptual activity of savouring.

PSC seems to imply that (momentary) passive touch and passive pain perception are not perceptual modalities. In neither does one undertake exploratory activity. In passive touch, one feels bodily contact, but not the properties of some external thing. (If one suddenly bumps up against something sharp, one feels a sensation on one’s skin, but not any external thing. If one runs one’s thumb across a knife-edge, one feels its sharpness.) In active pain exploration, one is able to report objective qualities of the pain. In passive pain, one suffers, but one cannot report objective properties of the pain. Passive pain and passive touch give rise to sensation (Aydede 2009), but they should not be regarded as perceptual modalities.

PSC gives a properly nuanced account of tactile-visual sensory substitution (TVSS), and of why intuitions can diverge regarding this prosthetic modality. In

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12 Here, I am indebted to Casey O’Callaghan for a very helpful conversation.
TVSS, a low-resolution camera image is projected on the tongue by an array of electrotactile “pins”—the brighter a pixel, the greater the current applied by the corresponding pin. (The same result can be achieved by vibrotactile pins on the subject’s back.) This results in a matrix of touch experiences, which, in a remarkably short time, resolves itself into perception that is vision-like with respect to perspective and motion (Bach-y-Rita 2004), though markedly low-resolution. (See Deroy and Auvray, forthcoming, for a discussion of whether TVSS affords direct perception of visual properties.)

TVSS activity is very much like looking, scanning, visually examining, etc. The camera that provides the image must be under the control of the subject, “zooming, aperture, and focus, and the correct interpretation of the effects of camera movement, such as occurs when the camera is moved from left to right and the image seems to move from right to left” (Bach-y-Rita 2004). What is vision-like in TVSS is the perceptual system, the suite of activities employed to take in a scene. Externalization of content too is visual: it needs perspectival changes. The TVSS subject has experiences as of visual objects and qualities by performing a visual tracking motion. This is the respect in which his experience is like vision. There is also a respect in which his experience is like touch—he can wriggle his tongue, for instance, and feel the buzz from the pins. So in this particular case, both the tactual and the visual perceptual systems can be brought to bear on the TVSS experience, giving information about quite different aspects of it. This explains why intuitions diverge.

IV. Cross-Species Identifications

One last problem. We noted earlier that honeybees and humans both have vision. But honeybees have very different ways of visually exploring their environments. Moreover, they have compound eyes and transducers that differ in kind from ours. How then can we say that both humans and honeybees have vision?

I have argued elsewhere (Matthen 2007) that homology is the right analytic instrument for judging sameness across biological taxa. In evolution, animals
develop functions specialized for the niches they inhabit, and in so doing, various morphological differences develop among organs that are nonetheless adjudged the same. Thus, bird eyes might be morphologically different from human eyes, and avian visual exploration behaviours, such as scanning, may be different from the corresponding human behaviours. The reason why they are identified is that they have a common “ancestor”. (The ancestor-relation on organs and on perceptual exploration behaviours correlates with that relation on organisms, and on developmental pathways.) That is, there is some ancestral organ from which bird eyes and human eyes both descended with modifications for specialized function. Similarly, there are genetically programmed visual perceptual activities in each that are physiologically very different, but which originate in the behaviour of an ancestral organism (Ereshefsky 2007).

With regard to vision, the oldest relevant homology concerns the opsins that transduce light. These originated from proteins that facilitate photosynthesis in green algae (Deininger, Fuhrmann, and Hegemann 2000). No other homology unites all visual systems. However, another important homology unites vertebrate eyes and distinguishes them from the compound eyes that invertebrates possess. (Vertebrate and invertebrate eyes originated independently, and have no common ancestor that is also an eye.) Presumably, perceptual activities such as scanning, circling etc., are also of relatively recent origin and divide vertebrates from invertebrates, and possibly (say) mammals from birds. Similarly, auditory systems are marked by a number of homologies, the most famous of which is not concerned with a transducer, but with the bones of the middle ear in tetrapods, which transmit energy from the eardrum. These descended from a jaw bone of fish.

In general, as the example of vision shows, homologies are nested, and correspondingly there are kinds of vision—vertebrate vision as against invertebrate vision. The same holds true of the very notion of sense. The approach I have taken here is to emphasize how the “traditional” senses provide information that is held in working memory for situation-dependent action. But another approach would be to treat all information-gathering faculties together, on the grounds that they descend
from very ancient systems such as bacterial phototaxis. These are simply different conceptions of *sense*, coextensive with different homologies. The advantage of the approach taken above is that it corresponds more closely to traditional treatments.

*Conclusion* The distinctions that are made between the sense modalities have scientific as well as everyday utility. There is, at best, partial overlap among the distinctions used for different purposes. Nevertheless, there appears to be a *basic* conception that scientists and ordinary folk agree upon: in humans, the senses are modes of picking up information about the world for the purposes of rational control of action and belief. The different senses correspond to differences in how information is picked up and used. Different conceptions of *sense* arise from emphasizing different aspects of the process.
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