Taxonomising the Senses

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Abstract:

> *I argue that we should reject the sparse view that there are or could be only a small number of rather distinct senses. When one appreciates this then one can see that there is no need to choose between the standard criteria that have been proposed as ways of individuating the senses – representation, phenomenal character, proximal stimulus and sense organ – or any other criteria that one may deem important. Rather, one can use these criteria in conjunction to form a fine-grained taxonomy of the senses. We can think of these criteria as defining a multidimensional space within which we can locate each of the senses that we are familiar with and which also defines the space of possible senses there could be.*

Key words: senses, perception, experiences, phenomenal character, representation, proximal stimulus, sense organ

The senses, or sensory modalities, constitute the different ways we have of perceiving the world, such as seeing, hearing, touching, tasting, and smelling. But what makes the senses different? How many senses are there? How many could there be?

Of any creature we can ask:

(1) How many token senses does it have?

(2) What types are those senses?

Types are general kinds of thing, and tokens are instances of types. For example, in the word "sense" there are four types of letter but five letter tokens. This is because there are two tokens of the same type: "s".

Questions 1 and 2 are very different questions, and it is important to keep them separate. To illustrate what we would be asking if we asked question 1, imagine that we came across a creature very much like a human but for the fact that it had four eyes—one pair above another. Call the creature "Four-Eyes". Four-Eyes might have one sense of vision, as we do, with all four eyes contributing to it, as our two eyes contribute to ours. Or Four-Eyes might have two distinct senses of vision, with each set of eyes contributing to its two different visual senses. If the latter were the case, and if Four-Eyes had no other senses, then it would have only one *type* of sensory modality, but it would have two *tokens* of that type. (Of course, for all I have said, Four-Eyes might indeed have three or four tokens of the visual sensory modality type.[1])

In this paper I will not discuss in detail the question of how we should individuate token sensory modalities, although this is an interesting question to investigate. Rather, I will focus on the question of how to taxonomise types of senses. What are the principles we should use for individuating the senses and how many actual or possible senses are there?

1. What Types of Senses Are There?

[1] Grice (1962) considers a creature like Four-Eyes. However, he puts his imagined creature to different philosophical use than I do here.

Many people have thought that there are only five types of senses. For example, Aristotle, in *De Anima*, famously said that there are five and only five senses: sight, hearing, touch, taste, and smell.[2] (He is talking here both about the number and kind of senses that humans have and the number and kind that animals have.) This view has echoed down the centuries, advocated by a number of scholars, most recently perhaps by Matthew Nudds who says that it is "obvious" that humans have five senses and that their having this number is a truth of folk psychology. Moreover, he thinks that it is not the case that "common-sense embodies the kind of proto-scientific understanding of the senses which is *liable* to revision or replacement."[3] Therefore, he holds that no amount of extra data from science could change our minds on the question of how many types of senses there are.

The commitment to the existence of only a relatively small, specifiable number of types of senses—typically, but not necessarily, five—forms part of what I call the "sparse view" of the counting question. The sparse view maintains the following:

- The number of possible sensory modalities is relatively limited.
- The sensory modalities are discrete.[4]

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[2] See book III, chapter 1. It is reasonably clear that Aristotle was claiming that as a matter of fact there are only five senses, and, given the nature of the world as he took it to be (composed of elements, each of which had different properties), there could be only five senses. Thus, he was claiming that it is nomologically necessary that we have only five senses. He was not claiming that it is metaphysically necessary.

[3] Nudds (2004, 35). On the same page, not only does he say that he has "not come across a good argument" for the idea that the folk notion of the senses is liable for revision, but he also says, "There have been authors who attempt to give a 'scientific' account of the senses, but they do nothing to show that they haven't simply changed the subject. Whatever they are giving an account of, it's not the senses as we commonly understand them" (fn11).

[4] It may be that no one has ever held the sparse view that I outline here, but parts of it have certainly been avowed, and the position serves as a useful stalking horse.

To say that the modalities are discrete is to say that all of the possible modalities are rather different and distinct from each other (not that the modalities cannot interact).

Should one believe the sparse view? I think not, for two reasons. First, there is evidence that many more than five sensory modalities *actually* exist. From these cases we can go on and extrapolate and thus come to believe that the number of *possible* sensory modalities is large.

Let us take the case of humans first. Many senses beyond the Aristotelian five have been attributed to humans. Some of the best candidates are:

- proprioception – comprising awareness of the position of the parts of the body, awareness of movement of the body and of how much force is required to move it[5]
- equilibrioception – the vestibular sense or sense of balance
- the vomeronasal system – detects pheromones using the Jacobson's organ in the nose and is separate from the olfactory system.

These are good candidates, because, plausibly, although by no means indisputably, they have some features that people have specified as necessary or sufficient for being a sense, such as having a dedicated sense organ, producing experiences with phenomenal character capable of being accurate and inaccurate, and being, at least partly, exteroceptive.[6]

Candidates for yet more human senses include distinctive pain, temperature and pressure senses instead of one amalgamated sense of touch.

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[5] The term "kinesthesia" is sometimes used interchangeably with "proprioception" thus defined. However, sometimes "kinesthesia" is used exclusively as a term for our sense of awareness of the movement of the body, while "proprioception" is reserved for the sense of the body's position.

[6] Note that the vomeral nasal system does not produce experience with phenomenal character but it does possess the other features.

Scientists have found that there are distinctive receptors that detect temperature, pressure, and painful stimuli and that there are separate spots in the skin receptive to pressure, warmth, cold, and painful stimuli. This has been the main reason that has persuaded some people that there are several senses here. However, in addition to this, some people have thought that the experiences of pressure, temperature, and pain are fairly distinctive; that is, they have rather different phenomenal characters. For example, it is sometimes claimed that Plato thought that temperature perception was a sense separate from that of touch and also that he thought pain was distinctive, being a sensation or "passion of the soul."[7] Moreover, he did this not because he knew of the differences in physiology that we know of today, but did so at least in part on phenomenological grounds.

Whether these are good enough reasons to postulate many senses in this case is highly disputed. One might doubt that pain, temperature, and pressure are particularly phenomenologically distinct. There seems, for example, to be a phenomenological continuity between experiences of excesses of pressure and temperature and experiences of pain. We also have evidence that a physiological overlap exists between the sensors that detect pressure, temperature, and painful stimuli—in both normal and pathological conditions. For example, pain seems to be elicited by extreme pressure or temperature (both hot and cold), suggesting that the mechanisms underlying experiences of each are not separate. However, this result might be explained away because it is hard to stop intense pressure and temperature stimuli from stimulating adjacent pain receptors in the skin. Nonetheless, there is more persuasive evidence in favor of continuity.

[7] See Classen (1993, 2).

Experiences of cold or vibration can inhibit the feeling of pain, and tactile acuity is diminished by painful heat experiences. Indeed, there is evidence of "multireceptive" neurons that are responsive to two or even three of these allegedly separate modalities, which some commentators claim indicate that the allegedly separate modalities are integrated centrally in the brain.[8]

Critics of the aforementioned evidence may think that these interactive phenomena are merely similar to the McGurk effect—and thus think of them simply as intermodal interactions between different senses. So, unfortunately, such evidence does not clearly settle the matter. Moreover, appeal to phenomenology to settle these issues is not straightforward since phenomenal facts are notoriously subject to dispute. Thus, there seems to be a large open question about whether there is one sense of touch or multiple, distinctive tactile senses.

Other candidates that have been considered as being additional human senses include senses of hunger, thirst, wet and dry, the weight of objects, fullness of the bladder, suffocation and respiration, sexual appetite, and lactiferousness.[9] Indeed, in their survey of the human senses, Rivelin and Gravelle have concluded that, "Five is obviously just not enough to account for the huge range of sensory possibilities of which the human species is capable; seventeen senses is probably a more accurate count."[10] This number may be well beyond the number one should endorse, but their survey gives an indication of the number of candidates that one may have to consider.

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[8] The evidence adduced here about touch is summarized in Craig (1996). Craig claims that temperature and pain processing are closely coupled structurally in the brain and that brain lesions rarely affect one without the other. The brain's processing of pressure is structurally more distinct.

[9] See Dallenbach (1939).

[10] Rivelin and Gravelle (1984, 17)

Outside the human sphere, there are even more candidates in the animal kingdom for being senses in addition to the Aristotelian five. For example, pigeons and other birds seem sensitive to the magnetic field of the Earth, which gives them a fantastic sense of direction.[11] It has also been shown that trout can be trained to strike at targets distinguished only by their position in a magnetic field. Moreover, a distinctive sensory organ and sensory system have been identified in trout that detect magnetic fields. This evidence has led people to think that all of the conditions required for positing a magnetoreceptive sense in trout have been established.[12]

Many fish and sharks seem to have an electric sense. Sometimes this sense takes a passive form, meaning that the creatures can detect electric fields that exist independently of them in the environment. However, there is another active form of the sense where the creatures produce an electric field and then sense changes to it. Some fish use this active electric sense for navigation and to detect other living creatures.[13]

A further apparently distinctive animal sense is infrared (IR) detection. All pit vipers and some boid snakes have pits on their heads that contain cells that are sensitive to infrared light. The pits are organs distinct from the snakes' eyes and nostrils and can be used to accurately detect prey when the eyes are covered.[14]

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[11] See Hughes (1999).
[12] See Walker et al. (1997), reported in Hughes (1999).
[13] See Hughes (1999).
[14] See ibid.

From this evidence, one can see that many good candidates exist for being a sense, distinct from the Aristotelian five.[15] Even if we required further information about these cases before we confidently asserted that they constituted senses, these examples suggest that there at least *could* be senses of many different kinds other than the Aristotelian five. The only way to resist this thought would be to claim, as we saw Nudds do earlier, that the folk psychological notion of the senses is such that, according to it, there are only the five Aristotelian senses and that this concept of the senses is such that it is not liable to revision or replacement by scientific discovery. Do we have good reason to believe that the folk conception of the senses is as Nudds claims? I think the answer is no.

One reason to think that the folk notion of a sense is not restricted to the Aristotelian five is that scientists are some of "the folk" and the number of senses that they recognize has frequently been altered. As we have already seen, the debate about how many senses there are is a present concern to scientists but the debate is not a modern phenomenon. The number of senses has been disputed throughout history by both philosophers and scientists. See Dallenbach (1939).

Another reason is that it is very plausible to think that if ordinary people heard the facts about other creatures' sensitivity to things such as magnetic fields, and they found out how creatures can act because of such sensitivity, or if they heard the facts about human proprioception and equilibrioception, they

[15] There are other examples that I have not discussed here. See, for example, ibid. and the essays in this volume.

would, I believe, unhesitatingly think of these as senses. I am happy to do so, and, in my experience, the average person shows no resistance to doing so.

An even more telling fact in favor of the view that the folk concept of the senses is not restricted to the Aristotelian five is that, in popular culture, the idea of senses other than the Aristotelian five abounds. How could this be unless the folk concept of a sense was such that it countenanced the possibility of additional senses? For example, in fiction there are accounts of possible senses such as these:

- X-ray vision
- mind-reading sense
- sixth sense—the ability to perceive the future, ghosts, and so on
- the Predator's infrared perception
- the Terminator's perception, which can analyze the composition of objects
- spider sense—the ability to perceive danger via a special tingling in the extremities

Thus, I see no good reason to think that the folk conception of the senses is committed to there being five and only five senses. Thus, I see no need to revise the folk conception in light of scientific evidence. I believe that the folk concept is simply silent with regard to the question of how many senses there are.[16] The number of senses seems to be left open by the concept of the senses that we

[16] Matthew Nudds (personal correspondence) is concerned that my account does not explain why people do say that there are five senses when asked and why this has not changed. I think that it is changing. Some people do not reply that there are five. Others who do, quickly rescind the view when other candidate senses are mentioned to them. No doubt most people have given the question little thought and reply automatically with the answer they learned from their preschool books.

have. The folk already embrace the idea that the number of *actual* senses is a matter to be determined by empirical findings, and they embrace the idea that the number of *possible* senses is greater than this. Thus, I believe, the folk concept is such that when new empirical evidence of the right kind is brought to light, that which is taken to fall under the concept of the senses can easily be enlarged without changing or revising the concept. This, together with the facts mentioned earlier, gives us good reason to think that there are, and could be, many more sensory modalities than the Aristotelian five. How many actually exist is a question that only progress in science, together with philosophical investigation into the conditions required for the existence of sensory modalities, will be able to shed light on.

Can we say anything further about the question: How many senses could there be? The answer depends in part on the question that forms the main topic of the next section. Therefore, I return to this question after considering how to individuate the senses.

2. What Makes a Token Sense an Instance of One Type Rather Than Another?

What determines that a sensory modality is the particular modality that it is, rather than another? To answer this question one would need to have a principle for *individuating the senses*. That is, you would need to be able to say what establishes that a sense is visual, say, rather than auditory, tactile, gustatory, or olfactory.

This individuation question has been the focus of much of the work in philosophy concerning the senses. As noted at the end of the last section, there is an obvious relationship between this question and that of how many senses there are. I believe that an explicit or a tacit acceptance of the sparse view about how many senses there are has influenced what people have often said about the individuation question—in a detrimental fashion. After elucidating the standard answers to the individuation question, I suggest another answer that rejects the sparse view and suggests that the number of actual and nomologically possible senses is rather larger than many have thought.

There are four main philosophical approaches to individuating the senses.[17] Important versions of the first two are broadly experiential approaches, holding that which sense is being used is determined by which features the perceptual experiences produced by the sense have. The other two are broadly physical approaches that hold that which physical factors are at play in the use of a sense determine which sense is being used. I discuss them in turn.

2.1. The Representational Criterion

One predominantly experiential approach is that a sense is individuated by which objects and properties the experiences in that modality represent. The classic Aristotelian view is one variety of this approach. According to Aristotle, there are "common sensibles"—objects or properties that can be detected by more than one sense. For example, shape is a common sensible as it can be

[17] See Grice (1962).

detected by both sight and touch. Others include motion, rest, magnitude number, and unity. There are also “proper sensibles”—objects or properties that can be detected by only one sense. With one exception, each sense has its own proper sensible, and representation of it is what makes the sense the sense that it is. For example, the proper sensibles of hearing, tasting, smelling, and seeing are sound, flavor, odor, and color, respectively. Touch is the odd man out as it has multiple proper sensibles, which Aristotle thinks are reducible to four basic ones: dry, fluid, hot, and cold.

There are many variants of the representation view. For example, one might think that there are a number of features, representation of which is necessary or sufficient or both for a sense to be the sense that it is. For example, one might think that vision essentially involves representation of the shape and size of objects in three-dimensional space at a distance from one’s body, as well as color and shades of light and dark. One might think that touch essentially involves the representation of the shape and size of objects that are in contact with one’s body and must involve the representation of temperature, pressure, and texture. What exactly one specifies for each of these senses will depend on thinking through a large number of examples of instances of sight and touch.

Another variant of the representation view would insist that the representation that we should consider when individuating a sense should not be, or should not *just* be, what is represented in experience at the conscious, personal level but what is represented by unconscious, subpersonal brain states or mechanisms. In other words, they would invoke an information-processing notion of representation wherein one attributes content to (perhaps) unconscious brain states involved in perceptual processing.

Some people will think that what is crucial in individuating a sense is the behavior that the sense allows a creature to engage in. For example, a sense might allow a creature to negotiate through its environment, avoiding obstacles at a distance from its body, or it might allow the creature to determine its position with respect to gravity or to magnetic fields. It is not unreasonable to include positions that make essential reference to behavior under the representational criterion. This is because when we ask how a creature can behave, the answer will very likely depend on what it knows or believes about the environment—in short, how it represents the environment to be. Some people might resist this because they hold a view of perception that denies that, in perception, representations are created in one's mind or one's brain. Rather, when perceiving, a creature directly responds either to the world or to the pattern of light in space and time that directly stimulates it.[18] However, although these views deny that representations are involved, one can argue that there is always at least a minimal sense in which perceptual states are representational. This is because, at the very least, experiences or other perceptual states of the creature can be assessed for accuracy, and the conditions in which the experience or state would be accurate can be taken to specify what representation is involved.[19] Alternatively, one could claim that the accurate description of the actions involved can be used to generate a set of objects and

[18] Some disjunctivists, followers of J. J. Gibson's ecological approach, as well as sensorimotor theorists, hold such a position.
[19] This has been argued for by Susanna Siegel (2010), where accuracy is elucidated as the conditions in which there is freedom from error.

properties taken to specify a relevant representational content. For example, if a creature can "avoid the obstacle to its left" or "bat the ball," then these descriptions of actions in part specify ways the world is or could be and thus could be taken as descriptions of representations relevant to determining the sense involved.

No doubt some philosophers would prefer to keep separate a representational criterion and a behavior or action criterion. However, nothing of import turns on this for my purposes. As long as one is clear about what form of representation, behaviour, or action one is using to individuate the senses, it does not matter whether one calls this type of criterion a representational one, a behavioural one, or an action one.

2.2. The Phenomenal Character Criterion

A second experiential approach is to think that what makes a sense the type of sense it is will be the nature of the phenomenal character of the experiences that the sense produces or involves. Immediately, however, one is faced with the question of how one might specify the sort of phenomenal character that all of the experiences of one sensory modality must have. It seems that when we specify the phenomenal character of an experience, we almost always say what it was an experience as of—that is, what the experience represented, whether or not that representation was accurate. So one might specify a class of experiences with a certain phenomenal character by specifying a class that represents certain things. In this respect, the phenomenal character criterion could turn out to look very much like the representational criterion. (Indeed, whether the nature of the phenomenal character of an experience can be fully specified *just* in terms of what the experience represents is a point much disputed in the philosophy of mind.[20]) For those philosophers who think that the phenomenal character of experience can be identified with the representational content of experience, the representational criterion and the phenomenal character criterion will be the same, but for those philosophers who deny this, they will be distinct.

Another way one might specify the sort of phenomenal character that all the experiences of one sense must have is to specify one type of experience and then cite a group of experiences related to it. An important and influential way of doing this is to define classes of experiences using a notion of global indiscriminability.[21] The hope is that we could define similarity classes corresponding to all and only those experiences that we intuitively would think of as experiences in each different sensory modality. One might then define each of the sensory modalities as being the one that produces the experiences in the appropriate similarity class.

2.3. The Proximal Stimulus Criterion

A physical approach, and one quite unlike the experiential approaches so far considered, is to individuate the senses by the nature of the proximal physical stimuli that affect the sense organ. The proximal stimulus is that which directly impinges on the sensory organ of the sense. For example, one might think that

[20] Tye (1995) and Dretske (1995), among others, argue that it is. I (2003, 2005, 2006), among others, argue that it is not.
[21] For more information on this methodology see ibid.

electromagnetic waves of between 380 and 750 nanometers are the proximal stimuli of vision, for those are what directly stimulate the cells in the eye. On this view, one is seeing if and only if one's method of perceiving the world involves the direct stimulation of one's sensory organ by such electromagnetic waves. One might think that pressure waves in a medium are the proximal stimuli associated with hearing. Thus, one would be hearing if and only if the proximal stimuli that affect the organ that one is using to perceive are pressure waves in some medium such as air or water. One might think the proximal stimuli of smell are the members of a class of airborne chemicals. One could similarly identify proximal stimuli for each sense.

2.4. The Sense-Organ Criterion

The second physical approach is to individuate the senses by the nature of the sense organ that one is using when perceiving. One might think that if eyes are used, then one is seeing; if ears, then one is hearing; and so on. However, it would seem incumbent on one to then give an account of what made something an eye, an ear, and so on.

One tempting way to do this would be to specify the nature of the sensory organs by specifying the nature of the proximal stimulus that affected them. For example, perhaps one might define an eye as being an organ that detects light waves and ears as organs that detect pressure waves, and so on. If one proceeded in this way, then the difference between this approach and the previous one would essentially collapse.

One could also define the sensory organs in physical ways. Thus, the physical makeup of the organ would be important. Indeed, one might not only want to mention the physical makeup of just the sensory organ but also include as part of the criterion the physiology of the whole sensory system, such as the nature of the nerves leading to the brain and even the relevant parts of the brain itself, in particular the cortical regions to which each sensory system projects. When I speak of sense-organ approaches, I include approaches such as these that include the whole sensory system.

2.5. The Standard Views and the Aristotelian Senses

Much of the philosophical literature on individuating the senses involves presenting reasons to favor one of these views over another. For the most part, the five Aristotelian senses differ fairly markedly on all four approaches from each other when they are operating normally and in optimal conditions. Those who support the sparse view of the senses would claim that this is evidence for their view that the senses are very different and discrete. To illustrate this, see the following table, which displays how one might think the Aristotelian senses differ on all four criteria suggested by the theories.[22]

	Vision	**Touch**	**Hearing**	**Taste**	**Smell**
Representation	Colour, shape and movement at a distance	Temperature, pressure, shape and	Sounds, volume, pitch,	Flavours (sweet, salty, bitter,	Odours located either in

[22] Of course, there are some reasons to question this neat dichotomy, even for the Aristotelian senses, as we will see in due course. In particular, it turns out that distinguishing taste and smell is particularly difficult.

	from our body in front of our eyes	movement at the surface of our body	objects being struck or vibrated at locations in and at distance from and all around our body	sour, umami) in the mouth or on the tongue or in the food touching the tongue	the nose or in the air around the nose, perhaps coming from a certain direction
Phenomenal Character	Visual experiences	Tactile experiences	Auditory experiences	Taste experiences	Olfactory experiences
Proximal Stimulus	Electromagnetic waves	Mechanical pressure and temperature	Pressure waves in a medium such as air or water	Chemicals that affect receptors on the tongue	Volatile molecules that affect the epithelium
Sense Organ	Eyes, particularly the retina	Skin or receptors in the skin	Ears, particularly the cochlea	Tongue, particularly the taste-buds on the tongue	Nose, particularly the nasal epithelium

However, the following create havoc with this neat taxonomy:

(1) non-Aristotelian senses

(2) tampering with the Aristotelian senses

(3) malfunction of the Aristotelian senses

(4) the Aristotelian senses operating in odd environments

These cases show (as will shortly be illustrated) that none of the four criteria allow us to neatly categorize each of the senses as being one of the Aristotelian senses or as being one of a small number of discrete senses. Furthermore, the four criteria pull us in different directions when we try to determine which type of sense a given sense is. This is one reason that people have thought that one has to choose between the four criteria for individuating the senses—they have thought that one has to pick the best out of the *competing* theories for individuating the senses. However, after outlining four examples that bring to light the most important problems these theories face, I suggest an alternative approach to individuating the senses. I claim that, in light of these examples, we have reason not to be sparse theorists and that, once we give up that commitment, we can come to see the four criteria in a new light. They are criteria that can be used together to allow us to accurately, nonarbitrarily, and in a fine-grained manner taxonomize the actual and possible senses.

2.6. The Standard Views and Bat Echolocation

Bats send out a high frequency "chirrup" and listen for the returning echo. Both the time it takes for the sound to bounce off objects and return to the bat and the direction from which the sound is returned (determined by the different times at which each ear is stimulated by the returning echo) are used to determine the size, shape, and position of objects at a distance in front of the bat. This means of perception allows bats to negotiate through their environment skillfully and quickly, dodging obstacles and catching moths and other prey in the dark.[23]

What do your intuitions say about this sense?

(1) Bats have an incredible form of hearing.

(2) Bats can see in the dark using this mechanism.

(3) Bats have a sense that we do not: echolocation.

[23] Further details of the bat's echolocation, together with excellent informed speculation on the representational and phenomenal nature of the bat's experience, is given in Akins (1993).

The proximal stimulus and sense-organ criteria tend to suggest that the bat has a form of hearing because the proximal stimulus is pressure waves and the sensory organ is an ear, or at least something more like our ears than any other organ. However, the frequencies that bats can hear are different from those that we can hear. So, to judge that the bat is hearing is to think that hearing involves the detection of any frequency of pressure wave, as opposed to just those that humans can detect. Similarly, the bat's ears are not physically exactly like ours. In addition, if within the sense-organ criterion we wish to include the brain mechanisms that process the signals coming from the ear, then because a bat's brain receives or calculates so much more information from its auditory signal compared to humans, there are numerous differences between the bat's brain and ours. So the bat's sensory organs are somewhat like ours, but somewhat not. In short, while the proximal stimulus and sense-organ criterion most naturally suggest that the bat is hearing, one could hold that the proximal stimulus and the sense organ are different enough from ours that the bat should be counted, on application of these criteria, as having a sense that we do not.

The representational criterion yields unclear results. One might think that it will yield the result that the bat is seeing because, using this sense, the bat can detect three-dimensional objects at a distance from its body, which humans can do with their sense of sight. However, the bat does not detect color, and some people have thought that perception of color is required for seeing. So alternatively, one might think that the bat really has a sense of hearing, for surely the bat's experiences will represent the sound that bounces back in the form of the echo. And indeed, one might question whether the bat's experiences represent where objects are at a distance from its body. One might think that instead, postperception, the bat judges where these objects are on the basis of things that it hears.[24] Alternatively again, one might be inclined to think that the bat's experiences represent both sound *and* objects at a distance from its body. If this is right, then perhaps the bat both sees and hears with the one sensory organ. Or perhaps it would be best to say that it has a different sense altogether from any of the ones that we have.

The phenomenal character criterion is unhelpful in this case. To the extent that we can imagine what it is like to be a bat one might think that their experiences share some auditory and visual characteristics with human experiences and perhaps have some unlike either of these.[25]

So what should we decide? In part we are ignorant of some facts, knowledge of which might help us determine which sense the bat has. However, I believe that even if we knew all of the relevant facts, our intuitions and criteria would tell us that the bat's sense is like our vision in some respects and like our hearing in others and like neither in some respects. Before exploring what we should do in the face of this, consider the other cases.

2.7. The Standard Views and Bee "Vision"

[24] Whether we can draw a sharp line between perceptual content and judgment is a highly debatable matter.
[25] Famously, philosophers have thought that one cannot know what it is like to be a bat. (See Nagel [1974].) However, Akins (1993) persuasively claims that we can know quite a lot about what it is like, even if not everything.

Bees are sensitive both to what we call visible light and also to ultraviolet (UV). If we look at many flowers in visible light, they often look like the flower on the left of the diagram (Fig. 1)—they have a small dark center and then a uniform color on the petals. However, if we photograph them using a camera sensitive to ultraviolet light, then the flowers often look like the flower on the right of the figure. The extra markings that can be detected using ultraviolet are called the "nectar guide" pattern, and they guide the bees to the source of the nectar.

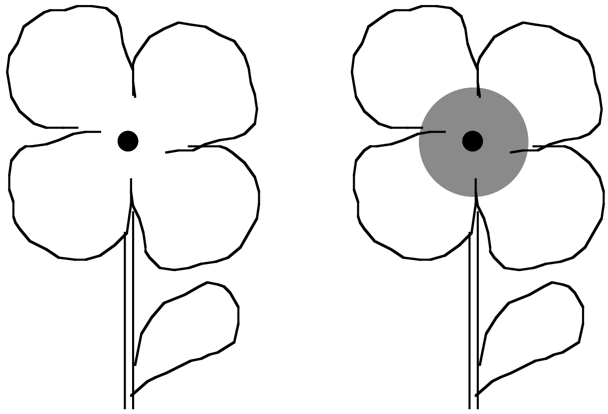

Fig. 1 Diagram of typical markings on flowers: in visible light on the *left*, and in ultraviolet light on the *right*

It is natural to say that bees have vision—a form of vision in which both the human visible spectrum and ultraviolet light are detected by the bees' eyes. But should we?

If we think that bee "vision" really is vision, and we think we should individuate the senses by the proximal stimulus criterion, then one must think that the proximal stimulus of vision is wider than the visible spectrum and also includes ultraviolet electromagnetic waves. However, if one is willing to extend the proximal stimulus beyond visible light, then should one extend it to the whole electromagnetic spectrum? One might think that one ought to. After all, one might think that all the electromagnetic wavelengths form a natural kind. What makes them different is merely their wavelength. However, if one does that, then one would be committed to thinking that a creature that detected only radio waves was seeing and that one that detected only gamma rays was seeing. Nevertheless, it is far from obvious that creatures with such detecting mechanisms, even if we were confident that they were senses, would really be ones that we would want to count as vision. I certainly would want to know a lot more about the sense in question, such as the nature of the sense organ, what the subject's experiences represented, and what their phenomenal character was before I would feel confident that the sense was vision.

Alternatively, perhaps we should limit the proximal stimulus of vision to encompass just visible light. In that case, the bee would either have vision plus some other sense, an ultraviolet sense, or just some sense other than vision—one that detected both ultraviolet and visible light. (A further case for the thought that we should limit the proximal stimulus of vision is outlined when we come to discuss snake infrared perception later.)

The sense-organ criterion yields unclear results. We do classify the bees' organs that detect visible light and ultraviolet light as eyes. Nonetheless, bee eyes are very different from human eyes. Bees have two large, compound eyes and three small, simple eyes (called "ocelli") arranged in a triangle on their forehead. When we learn just how different the organ of the bees' "vision" is to ours, it is not completely obvious that we should think of bees as having eyes.

The representational criterion perhaps delivers the clearest verdict that bees have vision. They would seem to represent what we represent—three-dimensional objects at a distance from our bodies. Perhaps they represent all of the qualities that we represent the world as having, plus some others visible only to those who can detect ultraviolet. Still, if that is right, then perhaps we should think that they have their own special vision-plus-ultraviolet sense. This is made all the more plausible when we consider that it is not clear that bees simply represent more than us—some extra ultraviolet facts. Humans have three types of cells in their eyes that are responsive to long, medium, and short wavelengths of visible light. The nature of these cells, plus subsequent processing, determines the kind of color vision that we have. Bees have three kinds of receptor, too, but theirs span both the visible and the ultraviolet ranges. Thus, the kind of "color vision" that bees have is rather different from ours. Bees do not see the colors that we see plus some other colors. They do not see, for example, how the flower looks to us under visible light *and* how it appears to us in a picture taken by a camera sensitive to ultraviolet light. Rather, they see the flower in just one way, determined by both the reflectance of visible light and ultraviolet light and by the nature of their light-sensitive cells. Because of this, it is tempting to describe the case as one in which bees do not see colors—or at the very least do not see the colors we do. And then if, with Aristotle, we thought that what made a sense vision was the representation of the colors—or at least the ones we see—it would be right to conclude that the bees do not see, although they do something similar.

Finally, think about the phenomenal character criterion. Of course, it is hard to know what the phenomenology of bee experience is like, but our best guess would be that to some extent it is the same and to some extent different from human vision.[26] The facts that make us think that what the bees' experience represents partially overlaps with human visual experience and partly does not motivates this thought. Here, a mixture of our ignorance and our best guess leaves us unsure as to how to classify bee "vision." It is somewhat like our vision and somewhat not.

Thus, although a few criteria suggest that bees have vision, the sense they have is sufficiently different from our vision that one might think it a different sense, even if it is most like our vision. This case shows that for each proposed criterion for individuating the senses, it will be difficult to decide upon the necessary and sufficient conditions that it takes to have a particular sense. We will see this problem manifest itself further in the next example.

2.8. The Standard Views and Snake Infrared Perception

It is interesting to contrast and compare the case of bee vision with that of snake infrared perception. Some snakes, such as pit vipers and boid snakes, have organs separate from their eyes that detect infrared. These organs are situated on the front of the snakes' faces, below the eyes and close to the snakes' nostrils. They consist of pits lined with infrared detecting cells.[27] Using this sense alone,

[26] Some people might even wonder whether bees (and other animals) are the subjects of any states with phenomenal character.
[27] See Hughes (1999). The relevance of this case to individuating the senses is also discussed by Gray (2005).

snakes can detect prey in front of them and discriminate the shape of the prey enough to allow them to make precise strikes on vulnerable parts of the prey's body. (This ability has been documented in a congenitally blind rattlesnake.[28]) Is this a form of vision or not? Let us run through the list of criteria again.

The proximal stimulus criterion is unclear. As with bee "vision" we face a decision as to whether we should extend the proximal stimulus of vision beyond that of human visible light, this time to include not ultraviolet but infrared radiation. If one thinks that one should do it for ultraviolet, then it will be hard to find principled grounds on which to exclude an extension to infrared. Then again, the question comes up: should it be extended to include detection of any part of the electromagnetic spectrum, including gamma or radio waves even if, intuitively, the detection of these waves would not yield a sense like vision?

The sense-organ criterion does not yield perspicuous results, either. The snakes' pits are like our eyes in some respects but not very many. The obvious question facing this criterion on consideration of this example is, What is it for something to be an eye? Right away we can see that any criteria for being an eye will be very malleable. For example, is an eye any electromagnetic detector or just a detector of all and only visible light or something else?

Another interesting question that the snake infrared sense raises, in addition to that of which sense it is, is whether it is a separate sense from what is commonly taken to be the snake's visual sense. Certainly the eyes and the infrared pits are different sensory systems to the extent that we think of them as formed by just the physiological structures near the surface of the snake's head.

[28] See Kardong and Mackessy (1991).

However, if we think of the sense organs as composing the whole physiological structure leading from the cells that light and infrared impinge upon to the central parts of the brain, which process the information gathered by those cells, the issue is far from clear. It has been found that the maplike visual and infrared representations of the world in the snake's brain are partly overlaid in the optic tectum. Some neurons in the tectum respond only to visual stimulation or only to infrared stimulation; others respond to either visual or infrared stimulation; still others respond only to a combination of visual and infrared stimulation. There may be enough overlap that one is tempted to think that both sets of organs (the snakes' eyes and infrared pits) are really organs of the one sense in the way our two eyes are organs of the one sense.

The question of whether the snake has one visible-light-plus-infrared sense or two token senses—either vision and an infrared sense or two token senses of vision—muddies the water in considering the nature of the snake's senses. For the rest of this section, I assume that there are two token senses and address the question of whether the sense that detects infrared is a sense of vision or not.

What does the representational criterion tell us? It is a reasonable assumption that three-dimensional objects at a distance from the snake's body are represented on account of the precise targeting of prey by snakes using only this sense. The infrared sense then shares a representational aspect with human vision. Nonetheless, the snake's infrared sense detects heat and does not detect the color properties that we detect, so there are considerable differences with regard to representation, too. These representational similarities and differences suggest that the phenomenal character of the snake's infrared sense may be somewhat like our vision but somewhat different. It is hard to say very much more than this.

In summary, the snake infrared sense is somewhat like our vision and somewhat not. Unlike the case of bee "vision," which involves detection of the part of the electromagnetic spectrum humans can detect plus an additional part, snake infrared perception does not involve detection of a part of the electromagnetic spectrum that humans can detect, merely detection of shorter wavelengths.

2.9. The Standard Views and Tactile-Visual Sensory Substitution

Tactile-visual sensory substitution (TVSS) devices try to replace the sense of sight by exploiting the sense of touch. A camera image drives a grid of vibrating pins that press against the back or other suitable expanse of skin. Areas of the camera image correspond to isomorphic areas of the grid of pins, and pressure and vibration against the skin correspond to the light levels the camera detects. With practice, subjects can use the system to skillfully navigate their way through the world and identify three-dimensional objects at a distance from their body.[29]

At first, subjects report that they are aware of the sensations on their skin, but as they continue to use the system they stop paying attention to or noticing the tactile stimulation, at least *as such*, and instead attend to or notice what

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[29] See Bach-y-Rita (1972).

seems to them to be the objects in the world in front of them. Reports about such subjects suggest that their experiences have much in common with visual experiences, particularly with regard to their spatial nature. For example, Nicholas Humphrey reports the following:

> By making use of information in the image about perspective and motion parallax, the blind subjects came to perceive external objects as being located in a stable three-dimensional world. They did not locate objects as lying up against their skin—any more than we with normal vision locate objects as lying up against the retina of our eyes—but immediately perceived them as being out there in space. (1993, 59)

Are people who use TVSS devices seeing, feeling, or perceiving in some different way? That is, are we replacing their vision, or are we extending their existing sense of touch to allow the detection of objects and properties it usually cannot detect, or are we creating a brand new sense? The sensory-organ criterion would yield different answers depending on what we say the sense organ here is. If it is the camera, then perhaps we should think that the sense at play is vision. If it is the skin, then we should think it touch. If it is the camera plus the skin, then perhaps the sense is neither vision nor touch but a new sensory modality. The proximal stimulus criterion is open to just the same sort of speculation. Is the stimulus the pressure on the skin, light on the camera, or both? Which one decides upon will determine whether the sense is touch, vision, or neither.

What does the representational criterion tell us? Certainly at first, when using the TVSS system, there is a representation of the pins touching the body.

This surely remains over time as the subject gets used to the TVSS system, even if it is not the main focus of subject's attention. The subject also seems to acquire a representation of objects in three-dimensional space in front of them. To this extent their experiences seem to represent in part what visual experiences do (minus color). Then again, if the subject has experiences with both vision-like and touch-like representational characteristics, then perhaps the subject has a sense that ordinary humans do not. The phenomenal character criterion yields much the same result here: one imagines the experiences, phenomenally speaking, to be partly like touch, partly like vision, and partly distinctive.

Thus, people who use a TVSS system, at least once they have adapted to it, are using a sense partly like vision, partly like touch, and partly unique.

2.10. Rejection of the Sparse View and How to Individuate the Senses

The criteria and our intuitions tell us that in each of the following cases:

- echolocation
- UV vision
- IR vision
- tactile vision

the sense involved is in some respects like our vision and in some respects different—sometimes like another one of our senses and sometimes different altogether. I suggest that these examples and others show that the actual and the possible senses cannot be clearly divided into a limited number of discrete kinds.

The differences between the senses amounts more to a difference of degree rather than a difference of kind.

Rather than try to pigeonhole all of the senses into a small number of discrete categories we should simply note what each sense is like with regard to each of the four criteria proposed by philosophers:

- proximal stimulus
- representation
- phenomenal character
- sense organ

(and perhaps others if they are required to fully capture all of the important aspects of the senses). For each criterion we can note how different or similar each sense is to one of the five Aristotelian senses if we like, but that is relatively unimportant. We should stop trying to artificially determine or stipulate which Aristotelian sense any sense is—or to shoehorn each sense into one of a small number of discrete kinds. It is because people have tried to do this and because the four criteria pull in different directions in problem cases that people have thought that they have to choose among the four criteria—rather than embrace them all.

For example, Matthew Nudds has suggested that our choice of which of the standard criteria we use to individuate the senses should be determined by their significance. This seems like a good methodology. We should ask, Why does distinguishing the senses matter to us? Nudds's own answer is that, "In distinguishing different senses we are distinguishing different ways of perceiving" (2004, 45). He goes on to explain that different ways of perceiving will involve perceiving different ranges of properties. Telling you which sense I am using to perceive something lets you know the type of properties that I (normally) know about.

However, I think that distinguishing the senses matters to us because we care about all of the following:

• representation

• proximal stimulus

• phenomenal character

• sense organ

Philosophers have argued over which is important, but why not think they all are? All can matter practically, and all can matter for determining both philosophical and scientific issues.

I hold that the four criteria are relatively independent dimensions along which different possible kinds of senses could take different values. We can think of these four criteria as defining a multidimensional space within which we can locate each of the Aristotelian senses, the four examples of unusual senses discussed earlier, and any other sense. Thus, human vision, bee "vision," snake infrared perception, and TVSS perception would each be located at a different place in the multidimensional space. Indeed, this multidimensional space is a way of delineating the space of all possible senses. All possible senses will occupy a place in the space.[30] (The actual senses will occupy a small number of these places.[31])

Plotting the actual senses in this space will allow one to see the similarities and connections between them yet, at the same time, to individuate the types of sense in a nonsparse, fine-grained manner. When we do such a plotting for the actual senses, we could do it for each token instance of a sense, or we could do it for idealized versions of the senses in each species. If we did the former, then my sense of vision might turn out to be a different sense from yours, for I may be much more nearsighted than you. If we did the latter, then we would have the same sense, for we each have tokens of the idealized sense of vision in humans. Also, if we did the latter, we might find that the actual senses are to be found in clusters in this space. For we will find, for example, that human vision and bee "vision" are closer together in this space than human vision and bat echolocation. Perhaps these clusters would correspond to the Aristotelian senses or the Aristotelian senses plus a few others. I suspect this might be the case. This would show us that the folk were trying to reflect complex facts about the types of senses that we find in the world using an oversimplistic model, but one whose origin is explicable given the facts. However, if two senses are close together in

[30] In the actual world there will of course be contingent connections between the criteria. For example, the proximal stimulus and the sense organ/physiology of the sense probably partly determine the representational properties and the phenomenal character of perceptual experience. The extent to which any necessary connections exist among the criteria is a difficult question and one's answer to it will depend on one's views on (at least) the following: the nature of phenomenal character, what types of metaphysically possible worlds there are, and whether a sense must generate conscious experiences. Thus, one might hold that while each possible sense will occupy some place in the multidimensional space, not every position in the space is a place that a possible sense could occupy.
[31] Of course, when faced with certain senses we may be ignorant of the nature of those senses with regard to the facts pertaining to one or more of the criteria, but that is merely our unfortunate epistemic situation. When we embrace all four criteria and resist shoehorning all of the senses into a few discrete kinds, we can simply note, for each criterion, all of the facts we know. For example, in assessing the nature of the sensory organ in TVSS we should mention both the camera and the skin of the subject and the connection between them.

this space, we should not concern ourselves with the question of whether they are the same sense. Once we have plotted their location in the space and noted their similarities and differences, we have said everything we need to say about the senses. That is when we should cease to ask how to individuate the senses.

3. Conclusion

I have argued that we should reject the sparse view that there are or could be only a small number of rather distinct senses. When one appreciates this then one can see that there is no need to choose between the standard criteria that have been proposed as ways of individuating the senses – representation, phenomenal character, proximal stimulus and sense organ – or any other criteria that one may deem important. Rather, one can use these criteria in conjunction to form a fine-grained taxonomy of the senses that takes each criterion into account. We can think of these criteria as defining a multidimensional space within which we can locate each of the senses that we are familiar with and which also defines the space of possible senses there could be.[32]

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[32] Perhaps with additional restrictions of the kind outlined in footnote 30.

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