AUDITION

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Casey O'Callaghan

Introduction

Vision dominates philosophical theorizing about perception, experience, and the mind. The psychology and cognitive science of vision have captivated philosophers, and other modalities of sensation and perception have received little consideration. Increasingly, however, philosophers recognize the drawbacks of this unbalanced approach, and interest recently has grown in providing an account of audition and its objects. The philosophical study of audition promises to enrich work on the nature and character of perceptual experience since hearing provides a distinctive variety of awareness whose features distinguish it from vision. Hearing poses challenging puzzles for any comprehensive, general theory of perception. In addition, a fertile and growing empirical literature exists to inform philosophical work. Attention to theoretical issues and experimental results in the psychology of audition raises fresh questions about the nature of sounds, and hearing and impacts longstanding philosophical debates about perceptual experience. I wish in this essay to provide the theoretical and psychological framework to the philosophy of sounds and audition. Four fruitful areas deserve attention: auditory scene analysis and the nature of sounds; spatial hearing; the audible qualities; and cross-modal interactions.

Auditory scene analysis

We hear many things. When walking the dog, you might hear the sounds of cars passing, a plane overhead, your own footsteps, and the rattle of metal tags. Among the things we hear are sounds. Sounds are the immediate objects of auditory perception in the harmless sense that whatever else you hear, you hear it in virtue of hearing a sound. Though you might hear an ambulance or a collision, you hear it by or in hearing its sound. Naturally, the philosophical investigation of audition largely concerns the perception of sounds. What, then, are the natures of the sounds we hear?

Consider the central task of audition. From complex patterns of pressure variation at your two eardrums, you are able to discern and listen to a variety of sounds in your environment. I now hear the sound of an unmuffled truck passing on the street behind me, the sound of music from speakers on my bookshelf, a voice calling from down the hall, and the sound of a vacuum running next door. Hearing furnishes information about what is around you, where it is located, what is happening, and how long it lasts (see Gaver 1993). It does so through your awareness of numerically distinct sounds that unfold over time. The proximal stimulus to audition, however, involves oscillations of two membranes within your ears. The mechanical vibrations of the eardrums hold complex information about your surroundings. Bregman (1990) likens the problem of extracting information about the sounds one's environment contains from wave oscillations, which he calls the problem of *auditory scene analysis*, to determining the number, type, and location of boats on a lake just by observing the motions of two handkerchiefs suspended into narrow channels dug at the lake's edge. The central problem of auditory perception involves the auditory system's capacity to discern from complex wave information the number, qualities, location, and duration of sounds and sources in one's environment. On the basis of pressure variations at your ears, you gain access to an abundantly detailed world of sounds, things, and happenings.

How audition carves a pattern of pressure variations into auditory objects, streams, or percepts is a question for empirical psychology. Criteria proposed include temporal and qualitative continuity, temporal and qualitative proximity, and coincident patterns of change through time (see Bregman 1990). Whatever the details of the mechanisms by which audition organizes the perceptual scene, features of auditory percepts bear upon philosophical characterizations of audition's content and of sounds. Auditory scene analysis constrains a theory of sounds under the assumption that sounds are represented in audition without wholesale illusion.

Philosophy traditionally has counted the sounds, along with the colors, tastes, and smells, among the sensible properties or secondary qualities. Locke, for instance, claims in his *Essay* that sounds, like colors, smells, and tastes, are powers of objects to produce experiences in sensing subjects (Bk 2, Ch. 8, section 14). Sounds, on this historically prevalent understanding, are *properties* or attributes either of sounding bodies or of a medium such as air, water, or helium. Pasnau (1999) revives an account according to which sounds are properties. Pasnau argues that sounds are identical with or supervene upon the physical vibrations of objects and bodies. Pasnau ascribes sounds to what we ordinarily count as the sources of sounds. As such, Pasnau's property view differs from the commonplace view that sounds exist within a medium in wave-like motion.

Perhaps the most important constraint on a theory of sounds stems from the fact that auditory scene analysis is the task of segregating sensory information into discrete, coherent auditory *streams* (see Bregman 1990). The immediate objects of auditory experience are dynamic streams that have duration and extend through time. The need to accommodate the temporal characteristics of auditory streams poses problems for those who identify sounds with properties of either the source or the medium.

Auditory streams are characterized by audible qualities such as pitch, timbre, and loudness, and may change a great deal over time while remaining the numerically same stream. Sounds are treated in audition as the bearers of audible qualities – as the particulars that ground audible quality grouping and binding. If sounds are the primary particulars audition tracks, and are characterized in terms of their own range of attributes, sounds themselves are not mere dimensions of similarity among other particulars. Sounds, then, are not properties. Furthermore, since a sound might start out loud and high-pitched and end up soft and low-pitched, sounds persist through changes to their audible attributes through time. Qualities, however, do not survive change in this way. The color of the wall does not survive the painting. The circularity does not survive the squaring. The sweet smell of apples does not survive the rotting. Auditory scene analysis supports the view that sounds are particulars that bear pitch, timbre, and loudness and survive qualitative change.

The predominant, science-inspired conception of sounds nonetheless holds that sounds are traveling waves. Sounds, that is, are, or depend upon, longitudinal pressure waves that propagate through the medium surrounding a vibrating object or interacting bodies (see, e.g., Perkins 1983; Armstrong 1961: 147–8). Sounds, according to a wave-based theory, travel at speeds determined by the density and elasticity of the medium from their sources outward toward perceiving subjects.

What is entailed by saying that audition represents waves is somewhat obscure, and there are several interpretations of what one is committed to in saying that sounds are identical with or depend upon waves. One view of sounds construed as waves holds that sounds are properties or attributes of the medium. Such a view suffers from the weaknesses of other property views. A psychologically plausible wave-based conception requires that sounds are particulars that survive change and bear audible qualities.

Perhaps surprisingly, some plausibility attends thinking that sounds are object-like particulars. The wave bundles salient to auditory perception have spatial boundaries, travel through the medium from source to subject, and are characterized by physical properties, such as frequency and amplitude, that determine pitch, timbre, loudness, and other audible qualities. Such object-like particulars might therefore bear audible qualities, survive change, stand in causal relationships to sound sources, and exist in space and time. Nonetheless, sounds do not inhabit time in the way that objects do. Sounds survive changes to their attributes as objects do, but also possess duration essentially. Sounds do not merely last through time; sounds are creatures of time. The identities of many common sounds, such as spoken words and birds' calls are tied to a pattern of changes through time. In contrast to objects, which intuitively are wholly present at each moment at which they exist, a sound must unfold over time. Hearing one syllable does not suffice to hear the sound of the word. A momentary sound is intelligible as a point-sized plaid particular.

Some suggest, therefore, that sounds are best understood as event-like particulars (Casati and Dokic 1994, 2005; Scruton 1997, forthcoming; O'Callaghan 2007). Sounds *happen*, *occur*, or *take place* in an environment populated with everyday objects and events. Sounds occupy time and have durations. Sounds figure in causal transactions. Construing sounds as events caused by but independent from their sources meets the constraints upon a theory of sounds and their perception that are imposed by auditory scene analysis.

Spatial hearing

Hearing provides information not just about the identities and characteristics of sounds and sources in your environment, but also about their locations. When you listen to the sounds around you, you learn something about where those sounds and their sources stand in relation to yourself. You learn whether the unmuffled truck travels from left to right or from right to left. You learn which speaker has ceased to produce sound, and whether the voice comes from up or downstairs. Audition, like vision, but probably unlike olfaction and gustation, is a spatial perceptual modality. Audible location is one key criterion for segregating sounds during auditory scene analysis (see Bregman 1990, Blauert 1997, Best 2006).

The spatial resolution limit of audition, however, lags that of vision by nearly two orders of magnitude. Though vision's directional accuracy approaches less than 1′ (minute) of arc, hearing is nevertheless capable of discriminating directional changes of roughy 1° of arc (Blauert 1997: 38–9). Hearing provides strikingly useful information about the direction of audible events on the basis of binaural cues that stem primarily from differences in wave onset time, amplitude, and phase (see Blauert 1997; Colburn et al. 2006).

Locational information furnished in audition is not limited to direction. Hearing also represents distance to sounds and sources in one's surroundings (see Blauert 1997). Thanks to auditory cues that include amplitude, timing of secondary reverberations, and transformations (*head-related transfer functions*, or HRTFs), due to the asymmetries of the head and pinnae (outer ears), you are able to discern in hearing whether the truck is nearby or far away, and whether the voice comes from the next room or down the hall. Sounds seem in ordinary hearing to come from outside the head, or to be *externalized* (see Hartmann and Wittenberg 1996). Headphone listening, in contrast, involves hearing sounds that seem to come from somewhere between the two ears. Hearing, in a wide range of common circumstances, therefore represents location in three-dimensional egocentric space.

Strong indications suggest that spatial audition presents sounds not as traveling or propagating through the environment as do sound waves, but as having stationary, distal locations. Though a sound might seem more diffuse in one's surroundings than its source appears, and though under certain conditions sounds seem to come from all around, as in night clubs with loud bass, a sound seems to travel toward you only when its source does. Consider how odd it would be to hear a sound to emerge from its source and then speed through the air toward your head as if it were an auditory missile. It would be equally odd to hear a sound emerge from its source like a water wave and subsequently wash through the air, into your ears, around your head, and past you. The point is that sounds do not, auditorily, seem to be located where the waves are. The locations of sounds you hear are connected with the locations of their sources in the environment. Since you hear sound sources only in virtue of hearing their sounds, hearing the location of a sound source depends upon locational information about the sound.

If this phenomenological claim about the audible locations of sounds is correct, then views according to which sounds are identical with, or supervene upon, sound waves must attribute systematic and pervasive illusion with respect to the experienced locations of sounds. Furthermore, if sounds indeed travel as do pressure waves, the apparent *temporal* characteristics that one experiences sounds to possess, including duration and patterns of change through time, are mere projections of temporal aspects of one's experience of the *spatially* extended wave bundle that passes. If sounds are waves, sounds themselves lack the durations we experience them to possess. A desire to capture the phenomenology of spatial audition, as well as its roles in acting upon and forming beliefs about the locations of things and events in one's environment, motivates several philosophers to propose that sounds are in fact located at or near their sources (Pasnau 1999; Casati and Dokic 2005; O'Callaghan 2007).

Philosophers on the whole, nonetheless, have been skeptical about the spatial characteristics of audition. Malpas (1965) claims that one could not, strictly speaking, discover the location of a sound, because sounds have no places. Nudds (2001, forthcoming) argues that sounds are not experienced as standing in any relation to the space they may in fact occupy. O'Shaughnessy (2002) argues that sounds never are heard to be at any place. In perhaps the most famous philosophical discussion of sounds, P. F. Strawson (1959: Ch. 2) claims that an exclusively auditory experience, unlike an analogous visual experience, would be entirely non-spatial. Hearing, he claims, unlike vision and tactile-kinesthetic experience, is not an intrinsically spatial perceptual modality.

The results of empirical research make such skepticism surprising. But Strawson, at least, does not wish to deny that under ordinary circumstances one might hear the locations of things, or even the locations of sounds, on the strength of audition. Rather, he claims, audition's spatial content depends upon that of another intrinsically spatial modality, such as vision or tactile-kinesthetic experience. Audition on its own would lack the resources to represent space. But the phrase "intrinsically spatial" is tendentious, and it is not clear that the exclusively auditory experience can be understood in a way that distinguishes audition from vision with respect to the capacity for spatial experience.

Suppose Strawson's claim is that a subject who enjoyed only auditory experiences without visual or tactile-kinesthetic ones would fail to experience space, while a subject who enjoyed only visual or tactile-kinesthetic experiences would experience space. That appears false. Even the most rudimentary auditory experiences furnish the materials for an experience with spatial attributes. Consider hearing sounds alternate between two earphones, or sounds projected from random directions, or a sound that changes direction. Research on neurophysiological representation of space supports the view that auditory spatial experience develops even in absence of vision (see Carr 2002). Perhaps no single perceptual modality on its own could provide an experience of space (see, e.g., Evans 1982, Noë 2004), but that strike is not exclusive to audition.

One could, however, enjoy a minimal or rudimentary experience that counts as auditory, but which is not clearly spatial. This seems possible. Suppose you hear a qualitatively uniform field in which sound seems to be all around. Imagine hearing just an invariant sinusoidal tone presented with no binaural directional or distance cues. Such an experience, perhaps, would not provide the materials for spatial concepts. But, plausibly, the same holds for visual and tactile-kinesthetic experience. Consider the visual experience of a uniform gray Ganzfeld, or the tactile experience of being immersed in the warm bath of a buoyancy-neutral sensory deprivation tank. Such experiences certainly count as minimal visual, tactile, and kinesthetic experiences, but, just as plausibly, do not count as spatial experiences.

Strawson's contention might amount simply to the claim that sounds themselves are not intrinsically spatial, or have no spatial characteristics intrinsically (see Nudds [2001] for discussion). Perhaps one could not enjoy a spatial but exclusively auditory experience because the proper objects of audition, sounds, have no intrinsic features that involve space. The objects of vision – colors and shapes – nonetheless are intrinsically spatial.

Perhaps the audible qualities of sounds, in contrast to the visual qualities of color and shape, or the tactile and kinesthetic qualities of texture, solidity, and bodily arrangement, are not intrinsically spatial qualities. Even if one might conceive of pitch and loudness without deploying spatial notions, perhaps one could not do the same for color or texture. One certainly could not do so for shape or arrangement. Though plausible, this does not debunk the idea that audition, even in isolation, is spatial. Unless pitch, loudness, and timbre exhaust the intrinsic qualities of sounds and are the sole objects of audition, it implies neither that sounds are not intrinsically spatial nor that one could hear a sound without experiencing space.

The truth in Strawson's observation is that sounds do not auditorily appear with detailed internal spatial characteristics, such as shapes or three-dimensional contours. Since sounds may seem to occupy greater or smaller portions of surrounding space, and some sounds seem point-like and others diffuse, this is best taken as an upshot of audition's resolution or grain.

Severe skepticism, then, appears unwarranted. Auditory perceptual experience constitutes a valuable source of spatial information about one's environment. The vast majority of commonplace auditory experiences are richly spatial, and audition's spatial content does not differ from vision's in requiring spatial experience in another modality. It therefore is plausible to hold that we learn about the spatial arrangement of sound sources by hearing sounds and their audible qualities as located in our surroundings. Sounds might even be intrinsically spatial if the natures of pitch, timbre, and loudness are not exhaustively manifested in experience or if sounds possess further attributes. Skepticism about the spatial characteristics of sounds and audition appears to trade on a particularly insidious form of visuocentrism. It mistakes reduced acuity in a particular modality either for parasitism or for outright incapacity.

Audible qualities

Sounds appear to have pitch, timbre, and loudness. The pitch of a piccolo's notes generally is higher than those from a tuba. Pitch comprises a dimension along which tones fall in a linear ordering according to height. The sound of a cannon generally is louder than that of a dog's bark. Loudness might be described as the volume, quantity, or intensity of a sound. Characterizing timbre is more difficult. Timbre is that attribute in virtue of which sounds that share pitch and loudness might differ in quality or "tone color." Thus, a clarinet and a saxophone playing the same note differ in timbre. Timbre has been described as "the psychoacoustician's multidimensional wastebasket category" (McAdams and Bregman 1979).

Though sounds are not best understood on the model of secondary or sensible qualities, audible attributes of sounds stand as correlates to the hues, tastes, and olfactory qualities. This suggests that familiar accounts of colors and other sensible attributes extend to the audible qualities (see Cohen, "Color," this volume). Pitch, for instance, might be a simple, unanalyzable, primitive property, a disposition to produce certain auditory experiences, or a physical attribute of sounds. What, then, are the constraints on an account of the audible qualities?

Physical science and psychoacoustics have taught that frequency, amplitude, and wave shape determine the audible qualities of a sound (see, e.g., Gelfand 2004). I will focus primarily on pitch since it often is compared with color (but see Handel and Erickson 2003). Though not all sounds have pitch, some pitched sounds have a simple, sinusoidal frequency, and some are complex with sinusoidal constituents at multiple frequencies. Nonetheless, the pitched sounds are those whose sinusoidal constituents, or partials, all are integer multiples of some common *fundamental* frequency. The pitched sounds, that is, all comprise periodic pressure variations that repeat some common motion at a regular interval whose inverse is the fundamental frequency. Thus simple sinusoids and complex waveforms that share fundamental frequency might match in pitch, though they differ in timbre. The phenomenon of the *missing fundamental* demonstrates that a sinusoidal constituent at the fundamental frequency need not be present for a complex sound to match the pitch of another sound, simple or complex, whose fundamental frequency it shares (Helmholtz 1954 [1877]; Schouten 1940).

A philosophical theory of pitch involves an account of the relationship between such physical properties as periodicity or frequency and the pitches of sounds.

A straightforward account is that the pitch of a sound is identical with its periodicity, a physical property we might characterize in terms of fundamental frequency. This account captures much of what we want from a theory of pitch. It explains the linear ordering of pitches. In addition, it captures the musical intervals and relations, including the *octave*, *fifth*, *fourth*, and so on. The musical intervals are pitch relations among periodic tones and amount to small integer ratios between fundamental frequencies. Thus, octave-related tones are those whose fundamental frequencies stand in 1:2 ratios. The fifth is a 2:3 relationship, the fourth, 3:4, and so on. Such ratios figure in adapting the pitch ordering to accommodate the sense in which octave-related tones are *the same* in pitch. Consider twisting the line into a helix, with successive octave-related tones falling at the same angular position. One gets the very strong sense that the natures of the musical relations are revealed by this discovery.

Some suggest that what we say about visible color holds for other sensible attributes such as audible and olfactory qualities (see, e.g., Byrne and Hilbert 2003). Physicalism, dispositionalism, or primitivism about sensible qualities, on such a view, transposes across the senses. I wish here to draw attention to two noteworthy places where arguments against a physical theory of color fail to transpose neatly to the case of pitch, and to two places where pitches raise difficulties similar to colors. The lesson is that we should not just assume that arguments effective in the case of color have equal force applied to other sensible qualities. Color, perhaps, is a uniquely difficult case, and theories of sensible qualities may not intuitively translate across the senses. At the least, we should take care to be clear upon which key points such theories turn.

Consider the following two counts on which a physicalist account of pitch fares better than color. First, consider the phenomenological distinction between unique and binary hues.

Some colors appear to be a mixture of other colors, and some do not. Furthermore, this fact seems essential to any given hue. Hardin (1993) issues a challenge to physicalist theories to explain the distinction in terms that do not essentially invoke the visual experiences of subjects. It is difficult, for instance, to see how "unique" reflectance classes differ from "binary" ones (see the section entitled, "Physicalism," in Cohen, this volume). But consider an analogous issue for pitch. Some pitched sounds seem simple, and others are comprised of discernible components. The difference, however, is captured by the simplicity or complexity of a sound's partials. Nonetheless, unlike the case of color, no pitch that is essentially a mixture of other pitches uniquely occupies a place in pitch space.

Second, no worry analogous to metamerism exists for pitch. Metamerism, or color matching among surfaces with very different surface reflectance properties, poses a problem for physicalist accounts of pitch because metamerically matching pairs share no obvious physical property. The worry is that no natural physical property exists that could count as the color. Consider pitch. Pitch matching does exist among sounds with very different spectral frequency profiles. For instance, a simple sinusoid matches pitch with each of the many complex sounds whose fundamental frequency it shares. For pitch, however, a single natural physical property exists which unifies the class. Each tone shares a fundamental frequency. Notwithstanding suspicion that physicalism for all sensible qualities stands or falls with the colors, pitch may prove fertile territory for a defense of a variety of physicalism for at least certain sensible qualities.

Philosophers must, however, deal with arguments concerning the viability of *any* physicalist or objectivist theory of pitch. Some such arguments are equally pressing in the case of pitch. First, substantial variation in frequency sensitivity exists among perceivers and is manifested, for example, in which frequency a subject identifies as *middle C*. More dramatically, an actual case of spectral shift, sometimes pronounced, exists for audible qualities in the form of pitch shifts commonly experienced by cochlear implant recipients. Perhaps it is more plausible that an objective standard exists for *middle C* than for *red*, but it is difficult to see how any given pitch experience holds definitive normative significance (see the section, "Physicalism," in Cohen, this volume).

In addition to confronting such familiar concerns, philosophers of audition, like philosophers of color, must contend with a controversy among psychologists and empirical researchers. The worry concerns the phenomenological adequacy of the periodicity theory of pitch and the threat of an error theory or eliminativism about pitch. Consider two sorts of psychophysical experiments. During *fractionalization* tasks, subjects are instructed to adjust a test tone until its pitch is half that of a reference tone. During *equisection* tasks, subjects are instructed to adjust several tones until they are separated by equal pitch intervals. In a series of classic psychophysics papers, S. S. Stevens argues on the basis of the results that pitch is not frequency (Stevens et al. 1937; Stevens and Volkmann 1940). Such experiments appear to show that equal pitch intervals do not correspond to equal frequency intervals. For example, according to these well-known results, doubling frequency does not uniformly affect perceived pitch. The frequency of a 1,000-hertz tone must be tripled in order to affect the same increase in pitch as quadrupling the frequency of a 2,000-hertz tone. The relationship is neither linear nor logarithmic. Fractionalization, equisection, and subsequent experiments reveal a scaling according to which pitch is a relatively complex function of frequency (see Stevens and Davis 1937: Ch. 3; Houtsma 1995; Hartmann 1997: Ch. 12; Gelfand 2004: Ch. 12; Zwicker and Fastl 2006: Ch. 5).

The pitch scale derived from such psychoacoustic data assigns to equal pitch intervals equal magnitudes measured in units called *mels*. The mel scale of pitch therefore is an *extensive* or *numerical* pitch scale, in contrast to the *intensive* frequency scale for pitch. The former, but not the latter, preserves ratios among quantities. The more recent *bark* scale, which is derived from features of the auditory system and not directly from psychophysical data, is a similar extensive pitch scale that closely resembles the mel scale (Zwicker 1961; Zwicker and Terhardt 1980).

Psychoacousticians, in response to such results, reject the identification of pitch with frequency or periodicity. The accepted view among auditory researchers is that pitch is a *subjective* or *psychological* quality merely correlated with frequency (see, e.g., Gelfand 2004; Houtsma 1995). Pitch, that is, strictly belongs only to experiences. The standard view of pitch thus is a form of error theory according to which pitch experience involves a radical projective illusion.

One might challenge the psychophysical results. Warren (1999), for instance, argues that subjects who attempt to estimate sensory magnitude instead appeal to some independent physical scale because “there is an obligatory interpretation of sensory input in terms of conditions and events responsible for stimulation" (111). This perhaps explains why musically initiated subjects frequently perform differently in fractionalization and equisection tasks. Laming (1997) objects to the claim that there is any such thing as a sensation to be measured, since to the subject "the stimulus is perceived as 'out there', not as an internal sensation (internal stimuli such as pain and tickle excepted)" (205). But even if we accept that subjects do not measure sensations, their patterns of judgment require explanation. It is natural to suppose that subjects respond based upon how they experience pitch. If relationships among experienced pitches differ from those among frequencies, then subjects misperceive relations that hold in virtue of pitch or else pitch is not frequency.[1]

Accepting that the mel scale is a well-founded measure that depends upon a genuine dimension of the experience of pitch need not, however, compel us to accept an error theory.[2] Several philosophical alternatives exist. One might accept either that pitches are dispositions to produce psychological states or that pitches are primitive properties of sounds. But one also might either retain the periodicity theory and explain experimental results in terms of pitch experiences, or seek a more adequate physical candidate for pitch. Empirical work on *critical frequency bands* (see, e.g., Zwicker and Fastl 2006), for instance, provides the materials either for an account of experiential discrepancies between pitch and frequency ranges or for an account according to which pitches are complex physical properties of solely anthropocentric interest (O'Callaghan 2002). What seems clear is that considering in detail the nature and experience of audible qualities promises insights into traditional debates concerning color and the sensible qualities.

Cross-modal interactions

The most fertile ground for future research on the nature, character, and function of perception does not concern experiences that take place within a given modality, but deals with interactions that take place among sensory modalities. A prominent empiricist understanding of sense perception assumes that one's overall perceptual experience amounts to the sum or compilation of experiences stemming from separate modalities of awareness, and that experiences of items and qualities that occur through different modalities exhibit distinctive characteristics.[3] Recent empirical work throws into doubt this traditional understanding of experience. Emerging evidence challenges the assumption that the senses function as independent systems and furnish encapsulated channels of awareness. Perceiving involves extensively comparing, weighing, reconciling, adjusting, and integrating the evidence of the senses. Experience is shaped by robust cross-modal interactions.

Consider ventriloquism. This well-established perceptual illusion, which need not involve speech, occurs when the visible location of a sound source affects the auditory experience of location (Howard and Templeton 1966; Bertelson 1999; Vroomen et al. 2001). The fascinating McGurk effect upon perceiving speech sounds involves a change to the phoneme one hears that results from watching the lips of a speaker pronounce a different phoneme (McGurk and Macdonald 1976).

Cross-modal illusions and interactions, however, are not limited to visual dominance. The recently discovered *sound-induced flash illusion* is a visual illusion induced by sound. Subjects shown a single visual flash with two audible beeps experience *two visual flashes* (Shams et al. 2000, 2002). Shams et al. claim that the effect is neither cognitive nor based on a strategy for responding to ambiguous stimuli. Rather, it is a persistent phenomenological change to perceptual experience. These and other cross- and inter-modal illusions, in which one perceptual modality impacts experience in another, call out for explanation (see Spence and Driver [2004] and Bertelson and de Gelder [2004] for further examples). The simple model of the senses as separate systems and atomistic modes of awareness requires revision. Conceiving of the senses as autonomous domains of philosophical inquiry has reached its limits.

I have proposed that to explain the adaptive significance of cross-modal illusions requires positing a dimension of perceptual content that is shared across modalities (O'Callaghan 2007). Such effects demonstrate a form of perceptual traction upon salient environmental sources of sensory stimulation. The mechanisms by which sensory information acquired through different modalities is reconciled otherwise remain unintelligible. Only under the perceptual assumption that auditory and visual stimulation, or visual and tactile stimulation, stem from a common environmental source do the cross-modal interactions that lead to illusion make sense as strategies for dealing with one's environment (Welch and Warren 1980). The principles by which stimuli are organized, adjusted, or reconciled must, moreover, construe significant environmental sources of stimulation in multi-modal or modality-independent terms, but not in terms specific to a single perceptual modality. Cross-modal illusions provide strong reasons to believe in certain unifying contents shared across perceptual modalities. Thus audition might furnish awareness as of things and happenings common to vision.

Traditional doubts concerning our capacity for perceptual awareness of particulars beyond sensible qualities perhaps, therefore, trade on an understanding of perceptual phenomenology grounded in an outmoded conception of the senses as discrete avenues of experience (see Russell 1912; cf. Lewis 1966). What is most striking about the perceptual modalities, including vision and audition, may be not the features distinctive to a particular mode of experience, but rather the ways in which they cooperate and interact to reveal a world of objects and events. Only attention to non-visual modalities makes this apparent.

Notes

1. This kind of issue, it warrants mentioning, is utterly common among sensory qualities. Brightness, loudness, and other intensities vary logarithmically with simple physical quantities.

2. The mel scale is not accepted as such by all. See Siegel (1965) and Greenwood (1997) for further empirical criticisms. But see Yost and Watson (1987), Bregman (1990), Houtsma (1995), Gelfand (2004), and Zwicker and Fastl (2006) for assent.

3. Thus many empiricists have resisted answering affirmatively Molyneux's question whether an individual born blind could, upon gaining sight, visually identify a shape formerly only felt. See discussions of the Molyneux question in Evans (1985), Campbell (1996), and Loar (1996).

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