Listening, Quantifying:

Intersections of Science, Acoustic Measurement, and Sound Studies

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ABSTRACT How does numerical measurement relate to sonic experience? Where does the subfield of physics called acoustics intersect with sound studies and phenomenological approaches to sonic knowledge? This paper addresses the origins of the decibel SI unit in sensory experience and compares scientific observation with phenomenological and sound studies definitions of listening.

The dualist foundation of modern empirical science is frequently treated by sound studies scholars as a negative ground against which to build alternative, non-dualistic approaches to structuring and sharing sonic knowledge. As a result, phenomenological studies and sound studies scholars have varied relationships with numerical measurement, which can both abstract sonic knowledge away from perceptual experience and root it in perceptual experience. Examining measurement scales, the process of scientific observation, and key moments in the philosophy of science, this paper attempts to explore and complicate the distinction between acoustic scientific knowledge and other varieties of sonic knowledge. How does scientific observation, knowledge, and transmission fit into the ways of observing, knowing, and transmitting suggested by sound studies and phenomenology? And

how does silence, the basis of acoustic measurement scales and also disparate ideas of sound, music, and noise, demonstrate or fail to demonstrate a common rootedness of these methods of knowing?

Intersections

Sound studies scholars propound an inspiring array of approaches to synthesizing, structuring, and sharing sonic knowledge. Many of these approaches respond to or attempt to transcend Enlightenment-era dualisms (subjective/objective, self/other, mind/material, senses/that which is sensed), treating sonic experience as a particularly poignant challenge to the hegemony of common Western models of knowledge. Deborah Kapchan writes, in her chapter on "body" for *Keywords in Sound*, a sound studies reader, "[H]ow might attention to sound and affect produce a body unfettered by the dualisms of the Enlightenment – mind/body, nature/culture, man/woman, human/animal, spirit/material?" (Novak 34). In this movement beyond mind/body dualism to more phenomenological and experimental approaches to studying sonic experience, some scholars seem to disown science as a field because of an assumption that it relies on a subjective/objective dualist ontology for its validity. In his contribution to *Keywords In Sound*, music anthropologist Veit Erlmann writes:

> "[A]s the physics of vibrating, resonant matter had become a cornerstone of the new experimental science at the heart of the Scientific Revolution, 'natural

> philosophers' increasingly invoked resonance for a larger, metaphysical agenda. Rene Descartes's work is a good example of this agenda…Although infamous for having single-handedly invented an entity we now call mind and for having degraded the body to a mere machine separate from the disembodied mind, the philosopher never quite renounced the notion of mind and body being cojoined…" (Novak, 177)

Rene Descartes, in fact, receives repeated call-outs as the originator of villainous ideas about the subservience of materiality to a disembodied, rational mind, leading to the marginalization of non-Western ways of knowing and sensing in academic institutions.

The present exploration is motivated by my own emotional reaction to this assumption: that of science's basis in the separation of subject from phenomenon being studied and therefore its incompatibility with first-person, phenomenological, and nondualistic approaches to sonic knowledge. As a student researcher in acoustics labs housed within physics departments and an improvising musician, I have experienced no incompatibility in the approaches to knowledge taken by scientists inside the laboratory and sonic thinkers and researchers located outside of it. In fact, I have found scientific observation to be an invitation to open the senses and bring my whole, embodied, intersensorial, culturally-embedded experience to bear upon hard problems. Rice's chapter in *Keywords in Sound*, on listening, captures my experience of scientific observation: "[L]istening as it occurs within the holistic context of lived experience," (Novak 108). The dissonance of reading sound scholarship that disowns

science while experiencing science as a valuable part of my sonic practice inspired me to examine the intersections of acoustic science and sound studies. Where does science live among the constellation of ideas, terms, and ways of knowing proposed by sound studies?

Simultaneous with a distancing from scientific approaches to knowledge, some sound studies scholars employ measurement scales developed in engineering and scientific contexts. The decibel, the Hertz, and sound power spectra make appearances in writings across musical anthropology, affect studies, and historical and contemporary sound studies. The separability of scales of measurement from their field of development is beyond the scope of this project; regardless, numeric units of measurement simultaneously abstract aspects of the sonic from and root them in perception. How does this abstraction supplement or contradict phenomenological approaches to sonic knowledge? Where and how do acoustic science, phenomenology, and sound studies meet one another? This project offers a sketch of several of these intersections and, more so, questions for further study.

Dualisms

Many sound studies scholars treat the plethora of dualisms offered by dominant modes of Western thought as a negative ground against which to construct nondualistic approaches to and definitions of sonic knowledge. These important efforts foreground other ways of describing, dividing, and valuing experience and the sensorium than those frequently assumed in Western academic contexts. In the process of moving

beyond dualisms, Descartes gets particularly maligned for his assertion "I think, therefore I am." While Descartes certainly built foundational ideas of the Western Enlightenment period, some of them dualistic, the notion that the *cogito* affirms the epistemological supremacy of a disembodied mind over perceptual experience is a misunderstanding of Descartes' skeptical philosophy.

The first appearance of the *cogito* occurred in a 1637 pamphlet as "je pense, donc je suis" (Stanford). By the publication of his *Meditations* in 1641, Descartes had revised and elaborated the phrase; the full sentence reads, "I doubt, therefore I am – or what is the same – I think, I am," (Descartes). Contemporary philosophers promote two interpretations of this statement, the inferential and the intuitive. The inferential asserts that Descartes inferred the *cogito* logically from first principles, while the intuitive school believes that the *cogito* is based on intuition (Stanford). I fall into the intuitive camp, largely because Descartes never wrote an inferential proof of the *cogito*, and he was nothing if not methodical about writing down logical proofs. The *cogito* is not an assertion that cognition, in the 21st century sense of the word, underlies our existence (that is anachronistic) but an affirmation of the experience of self-perception as the root of knowledge (Newman). He experienced himself doubting; therefore, something must exist to do the doubting. In his project of radical skepticism, wherein he tried to discard all existing knowledge and start from scratch, Descartes emerged with the conclusion that the first, and maybe only, thing we can know is our own lived experience. This conclusion is not incompatible with phenomenological approaches to

knowledge.

Some of Descartes' other work does contradict phenomenological approaches. He proposed absolute distrust of the senses, for example. However, he did not originate the mind/body, material/spiritual split, which had existed in Western philosophy for millennia. In fact, like many sound studies scholars, Descartes focused attention on an intricate model of the relationship between materiality and experience (Stanford). Several hundred years after he wrestled with how the body and awareness interrelate (in the pituitary gland, he concluded), founding phenomenologist Merleau-Ponty described how "the perceiving body was the site of enmeshment with the world," (Novak 39). Descartes' work scaffolded many of the Enlightenment-era dualisms to which sound studies reacts, but he participated in similar knowledge projects and grappled with similar questions to those addressed by sound studies scholars. He wasn't such a bad guy, and sound studies shouldn't throw out his ideas entirely.

Observation and Experience

I sought out accepted definitions of science to examine how their approaches to knowledge might overlap or disagree with sound studies'. My search focused on two prominent mid-20th century philosophers of science, Thomas Kuhn and Karl Popper.

As these two thinkers detailed, and as anyone practicing science in a lab can attest, science does not occur outside of our perceptions, consciousness, or culture, the aspects of experience treated by phenomenology. Instead, these aspects of

experience determine how we form hypotheses and practice science. Thomas Kuhn's most recognized contribution to the philosophy of science, the premise of his 1962 book *The Structure of Scientific Revolutions*, is the concept of the paradigm shift, wherein a community of scientists, practicing their particular culture of science, collectively alters how they observe and experience. A paradigm shift is "a transformation of the world within which scientific work was done," (Kuhn 6). Kuhn depicts the history of science, not as a progression from a less to a more knowledgeable humanity over millennia of consistent scientific method, but as a series of tectonic shifts through which science practitioners, in dialogue with their societies, perceive the phenomena they are studying in utterly different ways. Kuhn writes:

> "What differentiated these various schools was not one or another failure of method – they were all 'scientific' – but what we shall come to call their incommensurable ways of seeing the world [paradigms] and of practicing science in it. Observation and experience can and must drastically restrict the range of admissible scientific belief, else there would be no science. But they cannot alone determine a particular body of such belief." (Kuhn, 4)

For Kuhn, science is broad. Observation and experience determine the hypotheses examined by science, but science can reveal, construct, structure, or communicate knowledge beyond that indicated by observation and experience. Science is not a specific empirical practice limited to the post-1700s Western world but consists of a collection of "particular" cultures, present throughout human history, that observe experience and gain knowledge by doing so.

Kuhn's repeated use of the phrase "the world" and his description of "seeing" locate him firmly in a particular Western paradigm himself, but he promotes the validity of alternative practices of science even while writing from within one of them. He encourages the examination of science's fundamental assumptions as a requirement of science itself, and he erases the boundary between science and other practices of seeking knowledge:

> "Rather than being elementary logical or methodological distinctions, which would thus be prior to the analysis of scientific knowledge, [dichotomies between fields] now seem integral parts of a traditional set of substantive answers to the very questions upon which they have been deployed. That circularity does not at all invalidate them. But it does make them parts of a theory and, by doing so, subjects them to the same scrutiny regularly applied to theories in other fields." (Kuhn 7-8)

Kuhn demands that scientists examine the distinctions between their own way of pursuing knowledge and other approaches and that they question the dualities on which their own practice is based.

Karl Popper, in his 1935 volume *The Logic of Scientific Discovery*, provides a more succinct definition of science: "A scientist, whether theorist or experimenter, puts forward statements, or systems of statements, and tests them step by step…against experience by observation and experiment," (Popper 3). Popper discounts past

Western thinkers who sought a demarcation setting science apart from other ways of seeking knowledge; for Popper, the differences between science and other knowledge projects are cultural, and the primary requirement of science is that the hypothesis be stated and the observation of experience be methodical.

Observation of experience ties these definitions of science closely to phenomenology and other approaches to sonic knowledge, Western and non-Western, found in sound studies. Where science becomes narrower than sound studies, according to Popper, is that the observation of experience must be methodical. Nonetheless, with science defined broadly in this way, one can imagine phenomenological sound studies approached methodically and scientifically, and one can imagine science research taking place through various first-person accounts of sonic experience. Both can be tightly disciplined, and both can be unruly and serendipitous. None of these methods exclude the others, though particular scientific and knowledge cultures may reject one another's fundamental assumptions. Further, science is a meta-method by which, Kuhn argues, science's own foundations must be scrutinized, and by this statement he justifies any project rejecting subjective/objective, mind/body, senses/sensed, self/other dualisms assumed by the particular scientific culture of the 17th-20th century West. (The advent of quantum mechanics in the first half of the 20th century arguably eliminated some of these dualisms within scientific communities, and the paradigm shift toward understanding phenomena as probabilistic and co-extensive with the observer is perhaps ongoing in Western society more broadly.) Kuhn justifies Descartes' extreme skepticism and the novel approaches to sonic knowledge

described by sound studies scholars at the same time.

Where science may diverge from a phenomenological approach in its relationship to sonic knowledge is that, in addition to being rooted in our experience, intuition, spirituality, consciousness, and cultural expectations, it can also uncover or produce knowledge that contradicts our experience, intuition, and cultural expectations. Science is a lens that can extend and transform our experience; as the authors of *Keywords in Sound* write of sound studies, "Any intellectual engagement with sound will necessarily reshape its material significances and extend its metaphorical lives in particular ways," (Novak 9). Science can do this in ways unpredictable from the immediate sensations and intuitions of lived experience. Some sound studies scholars might argue that this destroys the very experiences studied, or that it informs them, or that it expands them, or that it simply shifts them. The particular goals of a strain of sound studies may determine the value placed on this contradiction of perception.

Science and sound studies approaches share one final, significant assumption: both knowledge projects prioritize the sharing of their outcomes through language. While science relies on statements formulated to be methodically explored and disseminated, sound studies formulates statements in a larger variety of formats to be disseminated. As people seeking knowledge, we really like to share experiences with one another.

The Decibel Scale, Sensation, and Abstraction

"[U]nits of measurement are essentials of science" (Klein 24), writes the author of *The Science of Measurement: A Historical Survey*, and there is a strong association between science/engineering and quantifying experiences. In addition to language, one way contemporary scientists share knowledge is by numbering things. In the case of acoustical science, that means decibels, Hertz, and a handful of rarer units related to sound pressure.

Measurement and numerical scales in general arise wherever people need to agree on things (taxes, fair trades) or build contraptions that extend our sensoriums and bodies (supersonic microphones, wrenches) (Klein 28). Units of measurement have existed in every civilization, predating written language, so that we do not know which person first decided to measure something (Klein 28).

Some units of sonic measurement center perceptual experience more than others. The phon (frequency-specific loudness), sone (loudness), and noy (sonic annoyance) all attempt to replace the decibel scales (dB, dBA, dBC) with units more attuned to sensory experience. Nonetheless, the decibel persists as the most widely used unit of loudness by physicists, psychoacousticians, and sound studies researchers, many of whom employ dB and Hz as means for communicating aspects of sonic experience.

The decibel was developed by the Bell telephone company and named for Alexander Graham Bell in response to the challenge of transmitting voices at audible levels over cross-country telephone wires (Klein 582). The team charged with developing the scale gathered thousands of New York City residents and measured their individual thresholds of hearing. They also measured the smallest detectable change in loudness for each person. They averaged across these thousands of "young, unimpaired" people and set the average quiet threshold as 0 dB, devising a logarithmic scale because humans can perceive sounds at such an immense range of sound pressures (Klein 577-578). The dBA, and a few other variations of dB, were later developed to account for humans' different experiences of loudness at different frequencies (Bragdon 51).

Decibel measurements do not reflect the lived experience of any individual and thus abstract loudness from sensation. Musical anthropologist Benjamin Steege expresses frustration with this tendency of acoustical measurement toward abstraction and writes, "Sensory experience, finally, is adduced only as a special case…[A]coustical knowledge remains set slightly apart from the sonic," (Novak 22). At the same time, the decibel scale retains a relationship, if complex, to sensation; any two hearing people sharing a space with a 120 dB sound will likely have distinct experiences, but both will probably report some kind of sonic intensity. The decibel scale was not formulated in the absence of perceivers; it was formulated to measure perception, albeit abstractly and imperfectly. Interestingly, despite its abstraction of loudness from sonic experience, the decibel was devised to facilitate a sonic experience, that of one person hearing

another at a great distance. This tool, built through abstraction, expands our capacity for new kinds of sonic experience.

Acoustical handbooks describe the dimensionlessness of the decibel scale:

> "From our knowledge of noise levels it is appreciated that the decibel (dB) is the ratio of one level with respect to a reference level. It therefore has no dimensions. To obtain absolute values the reference level must be known," (Cory),

and,

> "The physical measurement of a given sound is determined by measuring its pressure relative to a base or reference sound pressure. This difference indicates the intensity of a particular sound, or its sound pressure level (SPL). Decibels are dimensionless units used to describe sound intensity," (Bragdon 51).

The reference level to which these authors refer is the threshold of silence, a perceptual experience. Decibels are a relative numeric scale where the zero-point of the scale is human sensation.

Acoustical science is reported to have gone through several phases in its relationship to sensation:

> "At first [acoustics] dealt almost entirely with subjective sound – sound as perceived by the human ear-mind network. Next, it expanded its scope and aim to include measurement of the physical sound vibrations by which those subjective human perceptions were evoked. Finally, it broke free of the human

> limitation in another respect: it began to deal also with vibrations at frequencies totally unhearable to humans and with vibrations in media other than the atmosphere." (Klein 594)

Arguably, the posthumanist position advocated by some sound studies scholars should embrace the abstraction of acoustic measurement from sonic experience. Non-human living creatures and materials experience vibrations that humans lack the bodily equipment to experience, and acoustic measurement has enabled us to, for example, understand that whales and birds communicate with frequencies outside our own capacity to hear, or that objects in space emit vibrations that would sound were the vibration to propagate through intervening material. The abstraction enforced by numeric scales can be treated as a tool to usefully transform how we think about our sonic experience and expand our awareness of our own aural capacities and those of other beings; it can also be treated as destructive or negatively transformative of aspects of our sonic experiences. As in any observation, the observer and observation tools change the phenomena being observed.

Silence as That Against Which

The decibel scale, and every scale of sonic measurement, uses as its basis either the absence of perceived sound or the absence of vibration. A human with hearing and a body arguably cannot experience the total absence of sound. John Cage famously described his aural experience inside an anechoic chamber:

> "I entered one at Harvard University several years ago and heard two sounds, one high and one low. When I described them to the engineer in charge, he

informed me that the high one was my nervous system in operation, the low one my blood in circulation. Until I die there will be sounds." (Cage 8)

Sound and religion scholar George Prochnik, in his book on silence, writes, "[N]obody really triumphs in pursuit of silence in the strict sense of the word until they cease to exist. The pursuit of silence in this life is fated to be endless and imperfect," (Prochnik 19). Religious scholars in Buddhist and Christian traditions recognize the multisensory nature of hearing in describing thought and other sensory experience as components of sound and barriers to silence. Zen Buddhist icon Thich Nhat Hanh premises his book on silence with, "There's a radio playing in our head…Our mind is filled with noise," (Hanh 3). Effectively, to the living, hearing being, silence does not exist, regardless of how we divide our sensorium.

In parallel, in the realm of measurement, the total absence of measurable mechanical vibration in matter occurs only at a temperature of absolute zero, and vibrations fail to propagate only in a fairly strong vacuum. To extra-human measuring tools, too, silence is impossible outside of improbable, idealized conditions. Acoustic scientists rarely, if ever, use the word "silence" in their writings. The closest description to a state of silence I could find in the engineering and acoustics texts I examined is, "...P0 indicates the reference pressure considered to be the weakest audible pressure a young ear can detect under ideal listening conditions (0.0002 microbars)," (Bragdon 51). This is the definition of the threshold of hearing used as the basis of the decibel scale, and this is why the decibel scale is a dimensionless, relative scale; it exists only in dialogue with human experience. Silence is not measurable.

Sound studies scholars, acoustic scientists, and other sound practitioners alike contrast sound against a ground that does not exist. In her *Keywords in Sound* chapter on silence, Ana Maria Ochoa Gautier observes that:

> "silence is lived as one of the most intense experiences across cultures… The tension between the apparent acoustic impossibility of silence and the intensely contrasting experiences it provokes lies at the heart of the types of presence and affect invoked by the term." (Novak 183)

Silence is that against which we hear. It is the limit sound approaches and the limit of listening.

Experiences nearing silence, while characterized in one sense by absence, are often so striking as to be described as intense sonic presence. Thich Nhat Hanh writes, "Silence is often described as the absence of sound, yet it's also a very powerful sound," (Hanh 9), and sound studies scholar Julian Henriques offers:

> "The effects and affects of the intensity or overload of sound may be compared to the extreme underload that is produced both in the absolute silence of anechoic chambers, in meditation techniques using an image or repeated sound 'mantra' and in experimental conditions of sensory deprivation. Such extreme low threshold states break the norm of modest amounts of sensory stimulation." (Henriques 458)

The connections between meditation, mindful awareness, listening, and silence span

multiple spiritual traditions, indicating a broad association between silence and the untouchable treated by some religious and philosophical schools of thought. Per Prochnik, the religion and sound scholar:

> "Large numbers of people from almost every faith harbor associations between God, the state of godliness, and silence. Indeed, if one were to look for shared theological (as opposed to ethical) ground between religions, a good starting point would be silence." (Prochnik 5)

Thich Nhat Hanh declares, "This is the sound of listening, the sound of silence…God is a sound. The creator of the cosmos is a sound. Everything begins with the sound," (Hanh 10). We strive for silence, or a state of listening to listening itself, and we never quite attain it, except perhaps in those moments of transcendence in which we touch the untouchable. Henry David Thoreau wrote that "all sounds are, ultimately, servants and purveyors of silence," (Prochnik 10), and as sound studies scholars, acoustic scientists, meditators, or sound practitioners, maybe so are we.

Knowledge Projects

Sketching these intersections between sound studies, sonic phenomenology, and acoustic science reveals similarities and some divergences. Sonic phenomenology and acoustic science and measurement are not fundamentally opposed approaches to structuring and sharing sonic knowledge but instead overlap; they retain distinct identities as knowledge projects, but all treat sensory observation of sonic experience. Arguably, the methodical observation of experience indicated by science could make it part of the larger project of phenomenology. First-person accounts of experience may

be scientific, and scientific methods may incorporate phenomenological ones, even as particular schools or eras of sound studies and science may reject one another's fundamental assumptions. How can these fields dialogue to produce new kinds of research methods and meaningful scholarship?

Science does not rely for validity on subjective/objective dualism and in fact demands exploration of other approaches to knowledge and perception. In that sense, sound studies and its many approaches to sonic knowledge serve a scientific approach. As we learn to perceive and experience sound differently through these various knowledge projects, our scientific and sound studies paradigms will shift, and our areas of research will progress and grow. How can sound studies, as a younger field than our particular contemporary scientific culture, continue to question its own foundations as it matures? What will its paradigm shifts look like? Or does sound studies, by its nature, require each scholar or subfield to operate from a unique paradigm? How does that permit, inhibit, or encourage the sharing of sonic knowledge?

As our acoustic measurement scales evolve and are informed by a growing body of neuroscience and cognitive science research, they will continue to be rooted in perception while abstracting away from it, revealing or producing knowledge that contradicts the lived experiences on which they are based. Science will continue to challenge our perceptions, and sound studies will continue to challenge science's assumptions. It seems like a healthy symbiosis when approached nondualistically and without outright rejection of any one approach. The kinds of sonic knowledge

addressed by these knowledge projects varies, but all seem to converge on the goal of sharing sonic experience through written language. In what other ways can sonic knowledge, scientific and otherwise, be shared? How can these approaches to sharing knowledge become more inclusive of those sonic practitioners operating outside the confines of academic journals or languages widely spoken in academic communities? The unattributed quote, "Writing about music is like dancing about architecture," captures the challenge that sound-focused fields face in encapsulating sonic knowledge. Why writing? What other media are available, and will they be accepted by these research cultures?

Sound studies and acoustic science respond to silence as a ground of sonic experience. In what myriad ways can silence be experienced and defined within established research cultures? What additional concepts of silence can be found in sonic cultures globally? What do psychoacoustics, psychology, music theory, and historical musicologies have to say about silence? How have ideas of silence evolved throughout the history of these cultures and fields, and are there ideas of silence that contradict those outlined here?

The intersections between sound studies and sound science suggest extensive collaboration among sound studies scholars and researchers currently siloed in disparate academic departments. Consultation between acoustic physicists, musical anthropologists, sound artists, and religious scholars could yield beautiful and original approaches to the sonic. If one goal of sound studies is to explode our sound

knowledge paradigms, critical interdisciplinary debate and community-building should be considered a foundational practice, and sound researchers in any field should consider alternative methods for disseminating the sonic knowledge they uncover, analyze, and construct.

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