Measuring Is Making

The Radical Indeterminacy of Music

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ABSTRACT

In *Meeting the Universe Halfway,* the feminist theorist Karen Barad explores the indeterminate nature of measurement. Drawing on empirical research into quantum entanglement, they develop an axiomatic approach to configuring the fundamental interconnections between processes of measurement and making. This article builds on this aspect of Barad's work and uses it to consider how an indeterminate *measuring-as-making* process might manifest in music. By staging an encounter between the composer John Cage's investigations of indeterminacy and two contemporary pieces of music—*Space Golf* by Hen Ogledd and *Wildfires* by SAULT—the author considers how a Baradian theory of measuring-as-making can be used to offer new perspectives on musical creativity.

MUSIC AND INDETERMINACY: JOHN CAGE

In his classic text *Silence*, the composer John Cage set out to define two conceptions of indeterminacy in music: music that is indeterminate with respect to its composition, and music that is indeterminate with respect to its performance. Regarding indeterminate composition, Cage refers to his own piece, *Music of Changes* [1]: "[Whilst] chance operations brought about the determinations of the composition, these operations are not available in its performance," likening the performer to a builder who must strictly adhere to an architect's plans [2]. Cage puts forward *4 Systems* by Earle Brown as an example of a piece that is indeterminate with respect to its performance, stating, "there is no score . . . any of the interpretations of this material may be superimposed in any number and order" [3].

Alongside creating such frameworks for recognizing and using indeterminacy in music, Cage's interrogations operated at a more fundamental level, as he worked to understand indeterminacy and its impact on experience across numerous compositions. In discussing two other pieces—*Variations IV* and *Williams Mix*—he informs us, "They begin anywhere, last any length of time, and involve more or fewer instruments and players. They are therefore not preconceived objects . . . they are occasions for experience" [4]. Whilst Cage's experience of the nonexistence of silence in an anechoic chamber shaped his approach to thinking of sound *as* music, these experiments in indeterminacy also appear to have influenced his thoughts, and the notion of music as an "occasion for experience" indicates a more pervasive effect of indeterminacy. John Holzaepfel's liner notes for *Music of Changes*, which suggest that "Cage's notation heralded a new concept of musical time" [5], clearly reflect such a larger-scale disruption of experience for audiences and players, with the score requiring the pianist to create a nonsequential sonic experience that transcends conventional expectations of musical time. Cage's compositions were designed to ask questions about the substance of music, in terms of sound aesthetics, along with its capacity to exist *in* time and to create new perceptions *of* time.

It was not only audiences that were affected by Cage's experiments. While playing *Music of Changes*, the pianist David Tudor, for whom Cage wrote a considerable amount of music, said that he was "*watching* time rather than *experiencing* it" [6]. In his description of Tudor's approach to performing *Variations II*—a piece where both the performance and the composition process are indeterminate [7]—James Pritchett also conveys this sense of Tudor feeling outside of time and of watching time pass from a point of remove rather than being actively involved in the production of a musical experience. Pritchett relates that the pianist "did not interpret the measured parameters as describing the *sounds* to be produced, but instead as describing the *actions* to be made" [8]. Whilst this image of Tudor methodically performing a set of predetermined actions, rather than creatively interpreting Cage's score, might appear prosaic, it does suggest that the process created a new form of musical experience for Tudor himself. This is reflected in Pritchett's framing of the performance of *Variations II*—which involved "multiple layers of processing and switching"—as "an exploration of the possibilities presented" [9].

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MEASUREMENT AS MAKING

These considerations of the impact of a performer's *measurement* of time on both their own and their audience's *experience* of time connect to feminist theorist Karen Barad's reflections on the nature and consequences of measurement. In *Meeting the Universe Halfway*, Barad details the process of measuring a particle. An accurate measurement of a particle would require measuring its position. However, its position can only be accurately measured if we also measure its momentum. This creates a paradox, in that measuring the particle's position requires the use of a device in a fixed position [10], whilst measuring its momentum requires a device mounted on a moveable platform [11]. As a result, any attempt to capture a particle's position will result in the measuring apparatus impacting its momentum. At the same time, any attempt to measure the particle's momentum will interfere with its position. Barad draws on the physicist Niels Bohr's indeterminacy principle to elaborate on the consequences of this paradox, proposing that "The values of complementary variables (such as position and momentum) are not simultaneously determinate. The issue is not one of unknowability per se; rather it is a question of what can be said to simultaneously exist" [12,13].

Barad describes this dilemma of measurement—known as "complementarity," after Bohr's work—as "the impossibility of drawing any sharp separation between an independent behaviour of atomic objects and their interaction with the measuring instruments" [14]. Furthermore, Barad states, following Bohr, that the consequences of quantum mechanics in measurement pertain "all the way up" from atoms and subatomic particles to human perception [15]. This would suggest that, whether we are measuring the position of a particle or listening to a piece of music, what is measured cannot be fixed and "pre"-determined.

To illustrate this problematic nature of measurement, Barad describes the process by which a scanning tunnelling microscope (STM) can detect individual atoms. Between an STM and an observed specimen, there is an exchange of electrons, which—at the atomic level—becomes intertwined with "the electron 'cloud' of the surface atoms of the specimen" [16]. The critical point is that, for Barad, this demonstrates that "images or representations are not snapshots or depictions of what awaits us but rather condensations or traces of multiple practices of engagement" [17]. Essentially, STMs do not measure already-complete objects that are waiting to be measured; instead, they play a fundamental part in the coming-into-being of the measured object. Thus, there are no "determinate objects with determinate properties and corresponding determinate concepts with determinate meanings" [18]. In Barad's view, since measurable things do not exist in and of themselves, it follows that all phenomena come into being at the point of measurement taking place, and that the "measurer" is part of each new phenomenon. This has consequences for how we think about processes of creating and experiencing music, enabling us to extend Holzaepfel's contention about Cage's innovations in notation and understand how a new conception of musical time is more pervasive, encompassing listeners, composers, and performers as measurers and makers of time through the production of music.

More recently, Barad's discussion of "virtual particles" has further emphasized the problematic nature of measurement, describing these particles as "quantised indeterminacies-in-action" [19]. They propose that, instead of thinking of measurement as a process that takes place in a neutral context that does not affect the measurement (what Barad refers to as "the void . . . an absence of matter . . . no thing" [20]), it is vital that we recognize the impact that "vacuum fluctuations" *always* have on measurement. Barad's analogy is a silent, unstruck drum. Before a drum is struck, we might assume that it is silent because there is a complete lack of external vibration affecting it. However, Barad engages quantum field theory to suggest that we should not talk of an absence of vibration or displacement in the energy field in which the drum is situated. Rather, we should understand that the *average value* of displacements in the field is zero. In Barad's words, "virtual particles are not in the void but *of* the void" [21], and fluctuations in what might appear to be a vacuum are unavoidable. Although their conclusions are somewhat elliptical, framing virtual particles as the "conditions of im/possibility for non/existence" [22], essentially their point is that the intra-action of particles and virtual particles in a so-called vacuum means that existence is fundamentally indeterminate. Such an absence of any absolute point, or moment, of complete determination suggests that there can never be a definite point where indeterminacy does not exist. As such, given that nonbeing is part of any measurement process, Barad equates the creative process of making-measuring—what they refer to as "mattering"—with "radical openness [and] an infinity of possibilities" [23], an openness that derives from the fact that the entire edifice on which measurement is based is fundamentally indeterminate [24]. As I explore in the final section of this article, by aligning complementarity, a Bohrian quantum-classical continuum, and radical openness, Barad equips us with a means of understanding how any musical experience cannot help but be indeterminate.

MUSIC AND INDETERMINACY: KAREN BARAD

Throughout *Meeting the Universe Halfway,* Barad makes frequent use of the phrase "marks on bodies" [25], a reference to how bodies, or things, interact ("intra-act") with others, and where each leaves a trace of the encounter on the other. As "boundary-making practices that are formative of matter and meaning" [26], measuring apparatuses do not simply enable us to observe phenomena; but neither can we reduce their impact on how we perceive the world around us to mere influence. This suggests that any instrument—a piano for example—could be considered an apparatus of measurement-as-making; a perspective addressed by composer Lauren Redhead, whose performance analysis leads her to suggest that "the voice outside the body" comprises linguistic, signifying, resonant and echoing properties [27], and composer Matthew Sergeant, who proposes that a "human-violin apparatus" is formed from the "composite agencies" of the human

body and the violin [28]. A musical instrument is not only its maker's "measurement" of acoustics, harmonic theory, woodwork, metalwork, and possibly electronics, but when used to create music, it is also the musician's measuring apparatus. It allows the pianist to take a reading and express the results of their understanding of, and facility with, a number of music's raw materials, including harmonic theory, manual dexterity, melody writing, chord voicing, and awareness of genre, to name just a few. Making a piano and making any piece of music—and not just an indeterminately generated composition—are therefore acts of "boundary making": they construct the limits of the field of measurement. Pianos and pieces of music are the results of a significant number of material practices, and, at the same time, each can be said to "produce" the pianists and the listeners that engage with them.

Beyond the performance and production of music, given that the hearing of sound is a measuring of the frequency and amplitude of sound waves (qualities that we recode as pitch, rhythm, and volume in music), listening must also be defined in terms of the inherent indeterminacies that Barad describes. There is no absolute and completely determined sonic object for us to listen *to*, and neither is there a fixed point that we listen *from*, given that the whole process of measurement itself rests on the fundamental indeterminacy of being. In this context, it is worth reflecting on Cage's (and Tudor's) experiments in measurement; where Cage's indeterminately derived scores were the process of mapping a number of aleatory operations—for example tossing coins—to musical instructions (in the case of *Music of Changes*), and where performances were the result of mapping and measuring nondetermined musical instructions in order to produce specific musical gestures and sounds in performance (for example, Tudor's interpretation of *Variations II*). The Bohrian quantum-classical continuum would suggest that, although certain determinations would have been made by Cage and Tudor, these do not place a limit on what we might think of as the *amount* of indeterminacy in a piece. And similarly, neither would Cage's chance operations have been the sole instigators of indeterminacy in music.

Whilst Cage's work might appear radical, in terms of the demands it makes on performers like David Tudor and the philosophical questions it poses to listeners about the nature of music, Barad enables us to understand that Cage's music is no more indeterminate than other, more seemingly genre-bound works. This is not to say that Cage is incorrect in his views on indeterminacy in relation to musical composition and performance. In many ways, Cage's work demonstrates an acute awareness of how the impact of indeterminacy on human understanding problematizes established codes of musical creativity and experience. However, in his analysis of Cage's modernist creative sensibilities, music professor Benjamin Piekut proposes that Cage's work tends to set nature in opposition to society, where the former can be defined in terms of authenticity, whilst the latter is seen as merely artifice [29]. Here, Barad's ideas, rooted in a poststructuralist critical milieu that is more aligned to the more pervasive consequences of quantum theory, enable us to see that Cage's contentions don't go far enough to recognize that quantum indeterminacy is never *not* happening; that nature and artifice are equally the product of quantum indeterminacy. Just as Barad contends that quantum measurement occurs all the way *up* to the "classical" realm of human perception—which would include hearing, writing, or performing a piece of music—then Cage's propositions about indeterminacy in music need to be extended *down* to a more fundamental layer of quantum behavior. This is to say that indeterminacy in music is more all-encompassing than simply creating open-ended performance instructions or using aleatoric compositional techniques. My contention, therefore, is that indeterminacy in music is pervasive; that any—indeed every—piece of music is unavoidably indeterminate regarding its composition.

In the remainder of the article, I further reflect on notions of measuring as making, by focusing on two examples of this pervasive indeterminacy in music: the pop songs "Space Golf," by the British psychedelic pop group Hen Ogledd [30], and "Wildfires," by the anonymous British R&B, house, and disco collective SAULT [31]. On the surface, these songs sound more *determined* in their composition and execution than any of the indeterminate pieces that Cage references above. "Wildfires" has all the hallmarks of contemporary R&B in terms of its production and vocal stylings, which provide the setting for lyrics that express outrage at the death of George Floyd in 2020 [32]. Everything about the track is precisely conceived and constructed to deliver a piece of music that sits comfortably among a trove of similar tracks on the sprawling album *Untitled (Black Is)*, the first of two double albums that SAULT released in 2020. In many ways, given that "Wildfires" is part of a wider creative project that is both musically and culturally absolutely aligned with some of the most pressing issues of our time, it would be easy to say that it is anything but indeterminate. Similarly, "Space Golf" is completely designed; its opening harmonies give voice to the band's rootedness in folk musics, its disco beat and production style playfully engage with classic pop-rock tropes, and its lyrical swipe at Donald Trump—ex-U.S. President and golfing businessman—all sit neatly within the history of political pop music. Given these knowing references to popular culture and a range of musical styles, this carefully constructed track could be described as *meta-pop*: left-field popular music that, in the words of Susan Sontag in *Notes on Camp*, operates in "a certain mode of aestheticism." For Sontag, "camp sensibility is one that is alive to a double sense in which some things can be taken. . . . It is the difference between the thing as meaning something, anything, and the thing as pure artifice" [33]; and it is in this sense that we can discern the keen *determined* design of the track "Space Golf." Where Cage drew a distinction between nature and artifice, this track's constructedness appears to be an intrinsic part of its appeal; it is designed to be apprehended as an artifact deeply embedded in a wider cultural matrix.

Piekut relates that "central to modernist ideology is the idea that nature speaks for itself . . . and allows unmediated access to its object" [34], and Cage's views on indeterminacy

in music, where radical aesthetics and supposedly antihuman compositional or performance techniques give voice to authentic, naturally indeterministic processes certainly reflect this. For Piekut, Cage's work represents the apotheosis of Eurocentric high modernism, and his discussion of *Music for Piano* details how Cage—far from leaving his raw materials in their natural state—carefully selects, measures, quantizes, and amplifies them [35]. However, "Space Golf" and "Wildfires" are examples of how any form of musical creativity can be understood to be fundamentally indeterminate, and not simply indeterminate by design. "Wildfires" and "Space Golf" are as indeterminate as any of the music that Cage wrote, not because of the way that they have been designed or performed, but because at every stage of their construction, they are phenomena that have come into being by virtue of a measurement process. They are musical measurements, assessments, and approximations of a heterogeneous set of available materials.

The clarity that Barad develops around the complexities of measurement that result from complementarity and the fluctuations of virtual particles has significant consequences for our understanding of creative musical processes and listening. Where "Space Golf" exists in a matrix of musical intertextuality and cultural reference, its writers' use of these materials, along with their choice to use a specific set of instruments, are measurements that create an artifact with certain features. For Cage, indeterminacy in music was something that needed to be designed in, but indeterminacy is something that is happening whether a composer instigates it or not. As listeners, we also become entangled with the music we are listening to. This listening is itself a further set of measurements that generates a new phenomenon, which—in the case of "Space Golf"—is different again to Hen Ogledd's own measurement-as-music-making process.

With its references to Motown in both the rhythm and accurately crafted sound of the bass guitar and drum parts, the vintage reverb effects that color the vocals and handclaps, along with the minimal production that firmly place the track within a 21st-century R&B aesthetic, "Wildfires" does not "sound" indeterminate, but, again, all of these features are SAULT's measurements of a field of available resources. Barad's work enables us to understand that Motown is not a fixed and determined entity any more than a Fender bass guitar; both are simply their makers' measurements of a set of resources—musical, mechanical, electronic, and otherwise—that were available to them at the time. In this regard, "Wildfires" and "Space Golf" are no more or less determined than the music that Cage discusses, since any creative act can be understood to be a process of using the tools at hand—our ears, a recording studio, a voice, a bass guitar—as a means of taking a measurement of what already exists and producing a reading of that measurement in the form of a creative outcome (including the act of listening as a creative process in itself).

Beyond creative processes and aesthetic outcomes, what fundamentally aligns Cage's, Hen Ogledd's, and SAULT's work is the fact that they all share the radical indeterminacies that Barad talks about—they are phenomena that speak of the topologies in which they exist and that they co-create. This is the critical point that Barad's focus on indeterminacy and complementarity brings to bear, that takes their work beyond being mere postmodernism in quantum form. Cage's measurements of indeterminacy through composition and performance are neither more fixed nor more open-ended than the likes of Hen Ogledd or SAULT. *Music of Changes, Variations II,* "Space Golf," and "Wildfires" are all constructed boundaries that bear the marks of their makers' making-as-measuring process. These boundaries are topologies, moments of measurement that bring a piece into existence; where the measurement of a unit of time in *Music of Changes* also produces a piece of musical time, and the production of a 21st-century political soul track creates new connections to 1960s civil rights activism by referencing and updating musical production tropes. At the same time, listening to these pieces opens up the boundaries once more, since listening is also a boundary-making process that involves the intra-action of the listener and the listened. The pieces are fixed at the moment of production; each becomes part of a new topology that is instigated through listening.

While Cage's compositions were fascinating and necessary creative experiments in understanding indeterminacy, Barad's insights offer a more encompassing perspective, where songs such as "Space Golf" and "Wildfires" become as radically open as a piece like *Music of Changes*. As music-makers, Hen Ogledd, SAULT, and Cage are all measurer-makers of indeterminate phenomena, and as listeners we are also engaged in the production of new, indeterminate sonic worlds. This Bohrian indeterminacy that exists all the way *up* in music-making enables Barad to expand our understanding of creating and experiencing music, and as this article has shown, their work offers a range of opportunities to engage with the radical indeterminacy of music that goes far beyond modernist experiments in sonic and temporal aesthetics.

References and Notes

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3 Cage [2] p. 38.

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9 Pritchett [8].

10 Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham and London: Duke Univ. Press, 2007) p. 109.

11 Barad [10] p. 112.

12 Barad [10] p. 118.

13 My interest in this paper is not to offer a critique of the Bohr-Barad complementarity model but instead to use these ideas to think about musical creativity.

14 Barad [10] p. 308.

15 Barad again follows Bohr to assert that what happens at the quantum level also holds true at the level of everyday—what we could call "classical"—experience. In simple terms, there do not exist two domains of measurement, a realm of quantum mechanics operating invisibly at the atomic scale and a visible world that functions according to Newtonian laws of classical physics. On Barad's reading, "No evidence exists to support the belief that the physical world is divided into two separate domains, each with its own set of physical laws: a microscopic domain governed by the laws of quantum physics, and a macroscopic domain governed by the laws of Newtonian physics" (Barad [10] p. 110).

16 Barad [10] p. 52.

17 Barad [10] p. 53.

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33 Susan Sontag, *Notes on "Camp"* (London: Penguin Books, 2018).

34 Piekut [29] p. 138.

35 Piekut [29] pp. 148–153.

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