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Breaches and Boundaries in the Reception of New Technology in Music

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Technology plays an increasingly prominent role in music. Today most music is produced or consumed with the aid of technological devices. The recording industry is founded upon a series of technological innovations, ranging from the original Edison phonograph to the latest MP3 software compression algorithms.[1] Even a live concert by a symphony orchestra is

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1. David Morton, *Off the Record: The Technology and Culture of Sound Recording in America* (New Brunswick, N.J., 2000); Michael Chanan, *Repeated Takes: A Short History of Recording and Its Effects on Music* (London, 1995); and Timothy Day, *A Century of Recorded Music: Listening to Musical History* (New Haven, Conn., 2000). MP3 refers to MPEG Layer 3, an audio compression standard for encoding music; MPEG stands for Moving Picture Experts Group, which operates under the auspices of the International Organization for Standardization to develop standards for digital video and digital audio compression.

scarcely possible without microphones, mixing consoles, amplifiers, loudspeakers, and so forth. New electronic and computer technologies have left their mark, and have sparked the development of new sorts of instruments, such as the electric organ, the electric guitar, the synthesizer, and the digital sampler.

But the impact of technology upon music is not solely a twentieth-century phenomenon. Throughout history, new instruments and instrument components drawing upon the technological possibilities of the day have often incited debates as to their legitimacy and place within musical culture. The arrival of the pianoforte into a musical culture that revered the harpsichord was for some an unwarranted intrusion by a mechanical device.[2]

Scholars in the fields of musicology and the sociology of music are increasingly analyzing the role played by technology in music.[3] There is also growing interest within science and technology studies (including the history of technology) in sound, noise, and music.[4] Arguably, music technolo-

2. Tia DeNora, *Beethoven and the Construction of Genius: Musical Politics in Vienna, 1792–1803* (Berkeley, Calif., 1995).

3. Georgina Born, *Rationalizing Culture: IRCAM, Boulez, and the Institutionalization of the Musical Avant-Garde* (Berkeley, Calif., 1995); Tia DeNora, *Music in Everyday Life* (Cambridge, 2000); Simon Frith, *Performing Rites: On the Value of Popular Music* (Cambridge, Mass., 1998); Steve Jones, *Rock Formation: Music, Technology, and Mass Communication* (London, 1992); Fred K. Prieberg, *Musica ex machina: Über das Verhältnis von Musik und Technik* (Berlin, 1960); R. Murray Schafer, *The Soundscape: Our Sonic Environment and the Tuning of the World* (Rochester, Vt., 1994), originally published as *The Tuning of the World* (New York, 1977); Timothy D. Taylor, *Strange Sounds: Music, Technology, and Culture* (New York, 2001); Paul Théberge, *Any Sound You Can Imagine: Making Music/Consuming Technology* (Hanover, N.H., 1997); and Steve Waksman, *Instruments of Desire: The Electric Guitar and the Shaping of Musical Experience* (Cambridge, Mass., 1999).

4. Hans-Joachim Braun, "Technik im Spiegel der Musik des frühen 20. Jahrhunderts," *Technikgeschichte* 59 (1992): 109–31; Hans-Joachim Braun, "'I sing the body electric': Der Einfluss von Elekroakustik und Elektronik auf das Musikschaffen im 20. Jahrhundert," *Technikgeschichte* 61 (1994): 353–73; Hans-Joachim Braun, ed., *"I Sing the Body Electric": Music and Technology in the 20th Century* (Hofheim, 2000; reprint, Baltimore, 2002); Karin Bijsterveld, "'A Servile Imitation': Disputes about Machines in Music, 1910–1930," in Braun, *"I Sing the Body Electric,"* 121–47; Antoine Hennion, "An Intermediary Between Production and Consumption: The Producer of Popular Music," *Science, Technology and Human Values* 14 (1989): 400–424; James P. Kraft, "Musicians in Hollywood: Work and Technological Change in Entertainment Industries, 1926–1940," *Technology and Culture* 35 (1994): 289–314, and *Stage to Studio: Musicians and the Sound Revolution, 1890–1950* (Baltimore, 1996); Trevor Pinch and Frank Trocco, "The Social Construction of the Electronic Music Synthesizer," *ICON* 4 (1999): 9–31; Trevor Pinch, "Why You Go to a Piano Store to Buy a Synthesizer: Path Dependence and the Social Construction of Technology," in *Path Dependence and Creation*, ed. Raghu Garud and Peter Karnøe (Hillsdale, N.J., 2001), 381–401; Trevor Pinch and Frank Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer* (Cambridge, Mass., 2002); Susan Horning, "Chasing Sound: The Culture and Technology of Recording Studios in Postwar America," *ICON* 6 (2000): 100–118; Marsha Siefert, "Aesthetics, Technology, and the

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gies are amenable to the same sorts of analytical insights as technologies in general. In particular, the influence of technology in music raises questions as to the boundary between "instruments" and "machines" and the place of the latter within musical culture.[5] New technologies sharpen the perennial issue of what makes for good music and "art." They also challenge our notion of what counts as live entertainment: should one applaud when the performer is a machine?

One way of thinking about the approach we adopt in this article is to see the introduction of new technologies into music as a set of "breaching experiments." Such experiments, first introduced into sociology by Harold Garfinkel, serve as probes into how everyday social order is maintained. Garfinkel got his students (the experimenters) to breach taken-for-granted interactional conventions, such as routine greetings, and observe what happened.[6] We want to treat the introduction of new machines as prima facie cases of breaches in musical culture. Such interjections provide an opportunity to rehearse arguments about what counts as part of music and art and, conversely, what is appropriately delegated to machines; breaches of convention reveal underlying norms and values.[7] Indeed, our argument about the breaches new musical instruments produce can be extended to technology in general. That is to say, reactions to new technologies could provide a fertile research site for investigating how technologies in general are embedded within conventional normative frameworks.[8]

Capitalization of Culture: How the Talking Machine Became a Musical Instrument," *Science in Context* 8 (1995): 417–49; Emily Thompson, "Machines, Music, and the Quest for Fidelity: Marketing the Edison Phonograph in America, 1877–1925," *Musical Quarterly* 79 (1995): 131–71; Emily Thompson, "Dead Rooms and Live Wires: Harvard, Hollywood, and the Deconstruction of Architectural Acoustics, 1900–1930," *Isis* 88 (1997): 597–626; Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900–1933* (Boston, 2002); Elena Ungeheuer, "Ingenieure der Neuen Musik—Zwischen Technik und Ästhetik: Zur Geschichte der elektronischen Klangerzeugung," *Kultur und Technik* 15 (1991): 34–41.

5. For work on boundaries in science and technology, and between science and technology and society, see Thomas F. Gieryn, "Boundaries of Science," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff et al. (Thousand Oaks, Calif., 1995), 393–443, and Susan Leigh Star and J. R. Griesemer, "Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science* 19 (1989): 387–420.

6. Harold Garfinkel, *Studies in Ethnomethodology* (Englewood Cliffs, N.J., 1967). A useful discussion of Garfinkel's work can be found in John Heritage, *Garfinkel and Ethnomethodology* (London, 1986).

7. We are not interested here in the foundational issue of what the proper role of machines in music is but rather in what the introduction of machines tells us about what different groups of historical actors have taken to be essential features of musical creation, production, and dissemination.

8. See Carolyn Marvin, *When Old Technologies Were New: Thinking about Electric Communication in the Late Nineteenth Century* (New York, 1988).

In this article we focus on three cases of the reception of new instruments in the twentieth century: the player piano and other mechanical instruments, the "noise instruments" introduced by the Italian futurists in the 1910s, and the electronic music synthesizer developed in the late 1960s and early 1970s. The impact of the noise instruments was most dramatic in the world of classical music; the synthesizer's impact has been greatest in popular music. We deliberately combine these latter two examples as a way of making our argument range as widely as possible. This is not so far-fetched as it at first might seem. The noise instruments were often characterized as early synthesizers, and the synthesizer itself originated in the serious world of experimental and avant-garde music.

Early Mechanical Instruments

We will start with a brief examination of a relatively unknown debate arising from a mechanical innovation in an existing instrument. In the mid-nineteenth century, linked-key mechanisms and valves, such as are found on today's woodwind instruments, replaced the traditional method of controlling pitch on the flute—that is, using one's fingers to stop holes bored in the instrument. The new keys were easy to operate and facilitated the production of much more uniform and cleaner tones for individual notes. But they met with opposition, because they ruled out the possibility of making a "vibrato by simply moving the fingers over the sound holes" and diminished the player's ability to "correct out of tune sounds" by means of slightly altering finger positions.[9] One commentator, Heinrich Grenser, declared that improving tone quality by the use of keys was "neither complex nor art."[10] According to Grenser, "the real art" of flute construction was to build flutes that would enable flutists to play whatever they wanted without the use of keys.[11]

The kinds of boundaries drawn in this example between art and non-art, and between control and the loss of that control, are the ones we are interested in. The opposition of some musicians to keys and valves did not stop the technology from changing. In other cases, however, resistance to change and the accompanying debates over what counts as "real" music and art have been of enormous importance.

One well-known example of such resistance is the introduction of the

9. For discussion of this case, see Christian Ahrens, "Technological Innovations in Nineteenth-Century Instrument Making and Their Consequences," *Musical Quarterly* 80 (1996): 332–40.

10. Hubert Henkel, "Die Technik der Musikinstrumentenherstellung am Beispiel des klassischen Instrumentariums," in *Technik und Kunst*, ed. Dietmar Guderian (Düsseldorf, 1994), 67–91. All quotations from German and Dutch sources have been translated by the authors.

11. Henkel, 86.

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player piano at the turn of the twentieth century.[12] Player pianos, such as the Pianola and the Welte-Mignon, produced their music mechanically through a set of instructions stored on a perforated music roll. Their commercial success depended upon not only the standardization of music rolls but also important changes in cultural values.

The earlier success of the pianoforte was intimately related to the Victorian ideal of the so-called piano girl—the notion that every young, middle-class woman should learn to play music, preferably on the piano. To play the piano "demanded toil, sacrifice, and perseverance," which, like work, "built character, fortitude, self-control." The home, with the woman and her piano at its center, was considered a haven in the heartless world of industrial society.[13] Moreover, women were thought to be especially suited to producing such caring and restorative music.[14]

At first the piano trade thought of the idea of "a 'machine' to produce piano playing" as "ridiculous" and "preposterous."[15] Musicians, music teachers, and composers opposed the new machine, contending that one could copy sound but not interpretation; that mechanical instruments reduced the expression of music to a mathematical system; that amateur players would disappear; and that mechanized music diminished the ideal of beauty by "producing the same after same, with no variation, no soul, no joy, no passion."[16] One commentator was afraid that members of the "lower level" of society would copy the "cultivated class" in order to advance themselves.[17] Others feared that music would "lose its distinctiveness, its uniqueness as an experience."[18] After "several months of mechanical music," a critic said, a listener would miss the "hesitating sounds which once charmed him, that human touch which said something to him, although imperfectly."[19]

Opposition to the player piano and other mechanical instruments was

12. The player piano was far from being the first "automated" musical instrument. According to Helmut Kowar's recent bibliography on mechanical music, which encompasses 1,819 references, mechanical instruments date back as far as antiquity; see *Mechanische Musik: Eine Bibliographie* (Vienna, 1996).

13. Craig H. Roell, *The Piano in America 1890–1940* (Chapel Hill, N.C., 1989), 3.

14. That is, as long as the music was performed at home. Tia DeNora claims that in public performances in Vienna between 1780 and 1810 the female pianist became less and less common; "Gendering the Piano: Repertory, Technology and Bodily Discipline in Beethoven's Vienna" (paper presented to Center for Research into Innovation, Culture and Technology workshop, Brunel University, London, 1995). This may have been due to the style of piano playing inspired by Beethoven; in contrast to older playing technique, which favored physical reserve, the new style created a virtuoso-culture that prized an aggressive, dramatic, manly, and physically emphatic manner of playing.

15. Roell, 40.

16. Roell, 54.

17. Roell, 57.

18. Roell, 58.

19. Ibid.

equally vehement in the world of European music.[20] European critics also held up the beauty of imperfection as an argument against mechanical instruments, and characterized mechanical music as dull, tiresome, cool, and frozen. Art could "consist only in communication . . . from soul to soul, a communication that the machine is, and ever will be incapable of creating."[21]

Differing views about the importance of participation and the musician's role in interpreting a piece of music led to heated debates. The shift in music making that mechanical instruments brought about also affected musical composition. According to Ernst Krenek, the machine-like character, the inhuman "clearness, exactness and preciseness" of mechanical music, had by the 1920s become a recognized element of composition. But Krenek was not fully convinced. He felt that mechanical music left no room for the "primitive drive of musical man," for active participation in musical performance.[22] The Dutch composer Willem Pijper observed that the speed, power, and polyphony of the player piano meant "less than nothing [compared] to the mystery that was the living center of all art."[23] Another Dutch commentator noted that the mental process of overcoming technical difficulty was crucial to one's artistic development.[24]

Some mechanical instruments, such as the Welte-Mignon, enhanced the composer's control over interpretation.[25] Arnold Schönberg saw no special advantage in this, arguing that the composer's own interpretation should never be the final one.[26] Another commentator denied that the composer actually achieved this sort of control over the performance, since

20. In order to study the reception of mechanical and early electronic instruments within the world of European music we analyzed the following journals between 1910 and 1930: *Der Auftakt*, *Caecilia: Maandblad voor Muziek*, *Internationale Revue i10*, *Modern Music*, *Musical Quarterly*, *Die Musik*, *Die Musikblätter des Anbruch*, *De Muziek*, *La Revue Musicale*, *De Stijl*. References to articles in other music journals, such as *Pult und Taktstock*, *Melos*, and *Maandblad voor Hedendaagsche Muziek*, have also been included.

21. Vincent d'Indy, interview by André Coeuroy, "The Esthetics of Contemporary Music," *Musical Quarterly* 15 (1929): 246–67, 265. See also Alexander Jemnitz, "Antiphonie," *Anbruch* 8 (1926): 350–53; Ernst Krenek, "Mechanisierung der Künste," *Internationale Revue i10* 1 (1927): 376–80, 380; Erwin Felber, "Step-Children of Music," *Modern Music* 4 (1926–1927): 31–33, 32; Eberhard Preussner, "Das sechste Donaueschinger Kammermusikfest," *Die Musik* 18 (1926): 899–903, 901.

22. Krenek, 380.

23. Willem Pijper, "Mechanische muziek," *Internationale Revue i10* 1 (1927): 32–34, 33.

24. Herman Rutters, "De sirene als muziekinstrument," *Caecilia: Maandblad voor Muziek* 70 (1913): 1–8A.

25. Compositions for the Welte-Mignon could eventually be punched directly onto the music roll; in contrast, the music rolls for the Pianola were still produced by recording interpretations of famous performers. See Hans Heinsheimer, "Kontra und Pro," *Anbruch* 8 (1926): 353–356, and Henry Cowell, "Music of and for the Records," *Modern Music* 8 (1930–1931): 32–4.

26. Arnold Schönberg, quoted in "Äusserungen über 'Mechanische Musik' in Fach- und Tagesblättern," *Anbruch* 8 (1926): 401–4.

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the player piano remained sensitive to the particular circumstances in which it was played—responding, for example, to changes in temperature.[27] Others identified problems concerning stage performances. Erich Steinhardt, after attending a concert featuring a Welte-Mignon at Donaueschingen, noted that the public hesitated after the performance ended: "Should one applaud? For nobody is there. It is only a machine."[28]

In mounting their opposition to mechanical instruments, critics made explicit their own views concerning real art and interesting music and music making. Their arguments centered on the need for mastery of technique and control over interpretation, for romantic passion, expression, variation, and uniqueness, and on the appearance of a frightening democratization. Performers and music teachers probably also feared for their jobs.[29]

Some European composers and musicians, however, welcomed the new mechanical instruments. The composer and well-known music critic H. H. Stuckenschmidt wrote that such instruments could replace expensive musicians, were superior as performers of increasingly complex music, and expressed the spirit of the age more fully.[30] Others similarly stressed the need for clear and unsentimental music or saw particular potential in mechanical music composed for radio and gramophone—technologies that demanded rigorous, linear, and rhythmic music.[31] Support also came from American music educators, piano manufacturers, and music publishers, who thought that the player piano would lead to "an almost universal music education" and would therefore democratize music.[32]

American advertising campaigns for the player piano recognized the importance of artistic sensibilities and drew upon a new blend of work and leisure, production and consumption. Advertisers presented the Pianola as a real musical instrument that could reveal one's artistic sensibilities, a claim in line with the Victorian ethos of personal achievement.[33] By using

27. Hans Haahs, "Über das Wesen mechanischer Klaviermusik," *Anbruch* 9 (1927): 351–53.

28. Erich Steinhard, "Donaueschingen: Mechanisches Musikfest," *Der Auftakt* 6 (1926): 183–86, 184.

29. As Howard Becker notes in *Art Worlds* (Berkeley, Calif., 1982), 306, innovations in art often threaten art world participants who have acquired their conventions and mastered their skills through time-consuming learning processes.

30. H. H. Stuckenschmidt, "Machines—A Vision on the Future," *Modern Music* 4 (1927): 8–14; "Die Mechanisierung der Musik," *Pult und Takstock* 2 (1924): 1–8; "Mechanische Musik," *Der Auftakt* 6 (1926): 170–73; "'Aeroplansonate' (George Antheil)," *Der Auftakt* 6 (1926): 178–81; "Mechanisierung," Anbruch 8 (1926): 345–46; and "Mechanical Music," *Der Kreis* 3 (1926): 506–8.

31. See, for instance, Ernst Toch, "Musik für mechanische Instrumente," *Anbruch* 8 (1926): 346–49, and G. Schünemann, "Muziek en techniek," *Maandblad voor Hedendaagsche Muziek* 1 (1931): 4–6.

32. Roell (n. 13 above), 39.

33. A. W. J. G. Ord-Hume, *Clockwork Music: An Illustrated History of Mechanical Musical Instruments from the Musical Box to the Pianola, from Automaton Lady Virginal*

player pianos as soloists, in duets with famous soloists, or in live performances with equally famous orchestras, manufacturers underpinned the claim that the "reproducing piano is the highest expression of the artistic and mechanical genius of the musical instrument industries."[34]

Advertisements also stressed the potential for "effortless recreation, leisure, and immediate gratification"; the player piano offered respite from the stress of industrial life.[35] Furthermore, manufacturers saw an opportunity to "interest men in music," since "what could be 'unmanly' about operating a machine?"[36] In contrast to the piano, which was gendered feminine at this time, the player piano was depicted as a masculine technology. Rather than vanishing, the nineteenth-century association between playing a musical instrument and a sense of personal worth became mixed in with new leisure and consumption values: the artistic expression made possible by manipulating a machine could be combined with recreation for all.

These debates over the introduction of new technologies into music, like breaching experiments, make visible norms and values concerning the art of music and music making that are often taken for granted. We have seen the importance placed on control and personal achievement, the links drawn between irregularity, unpredictability, and creativity, and the part played by the new value perceived in democratized leisure (a point raised by both critics and proponents of mechanical instruments). These values and norms were strategically adapted by the promoters of the new musical instruments.[37] The blending of personal achievement (the loss of which had been feared by opponents of mechanical instruments) with democratized leisure (which had been seen as an advantage by proponents of mechanical instruments) in effect helped create a market for the player piano.

Electric and Electronic Instruments

In the twentieth century, electricity and electronics offered new opportunities for innovation. The telharmonium, the theremin, the Ondes Martenot, and the Trautonium were welcomed by composers for the variations in sound and tone color they created.[38] But most of these early instruments

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Players to Orchestrion (London, 1973), 84. By pressing a lever, for instance, the performer could execute "the different variations of forte and piano."

34. *The Piano and Organ Purchaser's Guide for 1919*, quoted in Roell, 44.

35. A point made by Théberge (n. 3 above), based on his reading of Roell.

36. Roell, 40.

37. Our view of norms here is not static and deterministic. Norms can both constrain and enable.

38. For overviews of these instruments, see Harald Bode, "History of Electronic Sound Modification," *Journal of the Audio Engineering Society* 32 (1984): 730–39; Joel Chadabe, *Electric Sound: The Past and Promise of Electronic Music* (Saddle River, N.J., 1997); Curtis Roads, "Early Electronic Music Instruments: Time Line 1899–1950," *Com-*

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failed to gain widespread acceptance. The telharmonium (invented before amplification and loudspeakers were available, and used to pipe music to Manhattan restaurants) failed because it was too big to transport, too expensive, and produced too much cross talk on telephone wires running through the same conduits.[39] The main problems with the theremin, played by moving the hands between two antennas, were its limited timbral range and the difficulties of learning to control an instrument that offered no physical feedback at all.[40] The theremin did at least find a home in film music and was later used to add electronic timbres to popular music. The Ondes Martenot acquired a small classical repertoire and was particularly influential in French music. The Trautonium is best known for its use in Hitchcock's movie *The Birds*. But it was the noise instruments of Luigi Russolo that produced the sharpest reaction and debate in the first part of the twentieth century.

THE NOISE INSTRUMENTS

Luigi Russolo, a painter by training, announced his new instruments in his futurist manifesto *The Art of Noises*.[41] According to Russolo, music had to be renewed by enlarging and enriching the limited range of timbres provided by traditional instruments with the infinite variety offered by noises. Listeners, surrounded by all sorts of machines, had become used to such a variety of sound that music needed microtones ("enharmonicism," in Russolo's term), instead of mere diatonism and chromaticism, in order to connect with the listener.

The *intonarumori*, or noise instruments, that Russolo built with help of his friend Ugo Piatti were able to produce such sounds. According to the musicologist Barclay Brown, who describes Russolo's instruments as some of the very first synthesizers, the noise-generating parts of these instruments were powered by electric motors, handles, or hand bellows, and each

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puter Music Journal 20 (1996): 20–23; Bryan R. Simms, "Electronic Music," in *Music of the Twentieth Century* (New York, 1986); Braun, introduction to "*I Sing the Body Electric*" (n. 4 above), 9–32; and Hugh Davies, "Electronic Instruments: Classifications and Mechanisms," in Braun, "*I Sing the Body Electric*," 43–58. For a detailed account of the history of the telharmonium, see Reynold Weidenaar, *Magic Music from the Telharmonium* (Metuchen, N.J., 1995); for the theremin, see Albert Glinsky, *Theremin: Ether Music and Espionage* (Champaign, Ill., 2000). See also E. Rebling, "Electrische muziekinstrumenten," *Maandblad voor Hedendaagsche Muziek* 8 (1939): 335–40; Herbert Weiskopf, "Sphaerophon, das Instrument der Zukunft," *Der Auftakt* 6 (1926): 177–78; and Jan F. van Dantzig, "Electrische muziek," *Maandblad voor Hedendaagsche Muziek* 6 (1937): 157–60.

39. Théberge, 43. See also Richard Barrett, "Nieuwe technologie, componist en compositie," *Tijdschrift voor Muziektheorie* 3 (1998): 125–33, and Weidenaar.

40. Théberge (n. 3 above), 44.

41. Luigi Russolo, *The Art of Noises*, trans. Barclay Brown (1916; reprint, New York, 1986).

sound-generating device produced a characteristic noise. Furthermore, each instrument had a mechanism to amplify sound and control pitch—a sort of chemically prepared drum skin on a frame with a vibrating wire attached to the center of the skin, creating a specific pitch.[42] Some of these noise-producing mechanisms were rotating disks with differing surfaces that caused the wire to vibrate. As Brown described them, the "bursters" produced a noise like that of "an early automobile engine" or "pottery falling," the "cracklers" made a "metallic crackling noise" in the high-pitched types and a "strident metallic clashing" in the lower tones, the "hummers" resembled the sound of "an electric motor or the dynamos of electric power plants," the "rubbers" made sounds like "a metallic scraping," and the "howlers" sounded like sirens. Not all the noises were industrial; some evoked the natural world. The "gurglers," for instance, produced a sound like that of "water running through the rain gutters of a house."[43]

Russolo envisioned new compositions, or "networks of noises," written for these new instruments. These, he thought, should be more than just imitations of surrounding noise: "The Art of Noises would certainly not limit itself to an impressionistic and fragmentary reproduction of the noises of life. Thus, the ear must hear these noises mastered, servile, completely controlled, conquered and constrained to become elements of art." Only by mastering the infinite complexity of noise, "multiplying a hundredfold the rhythm of our life," stirring the senses "with the unexpected, the mysterious, the unknown," could one truly move the soul.[44]

The first public performance of his compositions *Awakening of a City* and *Meeting of Automobiles and Airplanes*, in Milan in 1914, immediately created the uproar that Russolo and his fellow futurists had hoped for.[45] According to music commentators such as Nicholas Gatty, the futurists had broken the fundamental laws of nature and music by deserting tonality and regular rhythm.[46] Others, however, criticized the music as not sufficiently new or artistic. The composer Edgard Varèse, who was desperately seeking new sounds himself, considered futurist music a servile imitation of daily life.[47] The painter Piet Mondrian and the composer George Antheil claimed the same.

Such appraisals may have been aimed at the more traditional compositions of Russolo's brother Antonio.[48] Yet Mondrian's and Antheil's criti-

42. Barclay Brown, introduction to Russolo, 10–11.

43. Brown, 12.

44. Russolo, 86–87.

45. Russolo, 34.

46. Nicholas C. Gatty, "Futurism: A Series of Negatives," *Musical Quarterly* 2 (1916): 9–12.

47. Edgard Varèse, "Que la musique sonne," *Trois cent quatre-vingt-onze* 5 (1917): 42.

48. See Karin von Maur, "Mondrian und die Musik," in *Mondrian: Zeichnungen, Aquarelle, New Yorker Bilder*, ed. Ulrike Gauss (Stuttgart, 1981), 289.

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cisms were also motivated by their deep disagreements with Russolo over which characteristics of machines had the most artistic importance.[49] For Russolo, enharmonic complexity was the highest priority. Mondrian, however, wanted neoplastic art—art that did not deny reality but was abstract-real, expressing the deepest imaginable reality, pure and immutable. Neoplastic music, therefore, had to be made up of tone (sound) and nontone (noise), just as color (red, yellow, blue) and noncolor (white, black, grey) made up painting. Such music should be able constantly and rapidly to alternate tone and nontone in order to prevent silences that could be filled with the listener's individuality. Furthermore, successive tones should differ in volume and timbre. But the futurist instruments were not suitable for this sort of neoplastic music, as they were unable to stop sound abruptly. Thus, according to Mondrian, the noise instruments lacked the capacities needed to create real new music.

As mentioned above, George Antheil reached the same conclusions as Mondrian, though for different reasons. The premiere of Antheil's *Ballet Mécanique*, which featured ten pianos, a Pianola, xylophones, electric bells, sirens, airplane propellers, and percussion, had received a riotous reception at Carnegie Hall in 1927 (one newspaper headline proclaimed: "Mountain of Noise out of a Antheil").[50] But Antheil did not want to compose for the Italian noise instruments because "these had no mathematical dimension at all, nor claimed space, but just improvised noise that imitated motorcars, airplanes, etc., which is ridiculous and had nothing to do with music." For Antheil, time was the essence of music—it was music's fourth dimension, produced by rhythm, silences, and loops. Time, according to Antheil, was inflexible, rigid and beautiful, the very stuff out of which life was made. Never a modest man, Antheil claimed that *Ballet Mécanique* was the first work on earth composed out of and for machines, neither tonal nor atonal, made only of time and sound, without the traditional contrast of piano and forte.[51]

Despite such differences, all three of these artists—Russolo, Mondrian and Antheil—stressed the ability of machine-like instruments to produce precise music. Moreover, in their writings one can find the emergence of a new value, one placed upon controlling and mastering (even if only to a small degree) unpredictability and uncertainty. We call this "uncertainty re-controlled."[52] This element of unexpectedness and unpredictability, in one

49. Bijsterveld (n. 4 above).

50. Bijsterveld.

51. George Antheil, "Manifest der musico-mecanico," *De Stijl* 6 (1924): 99–102; "Abstraktion und Zeit in der Musik," *De Stijl* 6 (1925): 152–56; and "My *Ballet Mécanique*," *De Stijl* 6 (1925): 141–44.

52. This reminds us of the aleatoric principle in music, which, although known for ages, became especially popular after World War II. Aleatoric music involves the admission of a controlled degree of chance in its creation and performance—introduced, for

way or another, referred to a sort of transcendence made "present" and "trapped" by the new musical instruments. Russolo announced abstract noise music that stirred the senses "with the unexpected, the mysterious, the unknown." Mondrian wanted instruments to produce a controlled irregularity expressive of the deepest imaginable reality. Antheil used the unpredictability of machines to search for an inflexible time-form capturing the fourth dimension of music. Thus, the romantic ideal of transcendence and the Victorian ideal of control began to fuse together in the new noise and machine-like instruments.

Russolo's instruments were a commercial failure. Sadly, only two pages from the score of *Awakening of a City* have survived, and none of the *intonarumori*. Some were probably cannibalized by Russolo himself for new uses, others lost during World War II. Between 1913 and 1927, however, Russolo's concerts were a success, with some thirty thousand people attending a series of performances in London.[53] Russolo made money out of his instruments by using them for the accompaniment of silent movies, but the rise of the "talkies" put an end to that. He took up painting again and became involved in mysticism and theosophy. He died in 1945, an ascetic recluse, having turned his back on the noisy world that had once inspired him.

THE SYNTHESIZER

The most successful electronic instrument of the twentieth century is the synthesizer.[54] It offers a far greater range of sounds and more ways of controlling sound than instruments like the theremin, Trautonium, and Ondes Martenot. Since its development in the early 1960s it has been widely used in many musical genres and become part of the leisure and entertainment industries broadly conceived. We will briefly describe the early development of the synthesizer before turning to examine a debate among synthesists as to what synthesizers can and cannot do.[55]

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instance, by using dice in composing, or by allowing performers to choose the sequence of a strictly specified set of fragments of the composition.

53. Ingo Bartsch et al., *Russolo: Die Geräuschkunst, 1913–1931* (Bochum, 1986), 21.

54. One should note here also two other very successful electric instruments, the Hammond organ (which, like the telharmonium, uses an electromechanical source of sound, the spinning tone wheel) and the electric guitar. The Hammond organ was very popular in churches in the 1950s and then later as a pop instrument; see Théberge (n. 3 above). On the development of the electric guitar, see Waksman (n. 3 above) and Rebecca McSwain, "The Social Reconstruction of a Reverse Salient in Electric Guitar Technology: Noise, the Solid Body and Jimi Hendrix," in Braun, "*I Sing the Body Electric*" (n. 4 above), 198–211.

55. Our research on the synthesizer focuses primarily on the period 1963–75 and has involved archival research and interviews with pioneering engineers and early users. See Pinch and Trocco, "The Social Construction of the Electronic Music Synthesizer"; Pinch, "Why You Go to a Piano Store to Buy a Synthesizer"; and Pinch and Trocco, *Analog Days*

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FIG. 1 Moog modular synthesizer, Model III-C, with sequencer complement, 1970. (Collection of Roger Luther, courtesy of MoogArchives.com.)

The name "synthesizer" was first given in 1958 to the RCA Mark II Synthesizer, a room-sized piece of tube-based equipment, programmed from paper tape, installed at the Columbia-Princeton Electronic Music Center.[56] The first commercial synthesizers used transistors and were developed independently in 1964 by Robert Moog on the East Coast of the United States and Don Buchla on the West Coast.

The Moog and Buchla synthesizers consisted of sound generators (oscillators that produced different waveforms and white noise) and processors (filters and envelope generators) connected by patch wires in endless combinations.[57] Analog voltage control technology enabled the pitch of

(all n. 4 above). For the attitudes of musicians concerning what synthesizers can't do, we rely upon interviews with well-known 1970s synthesists conducted for *Keyboard* magazine and collected in Tom Darter and Greg Armbruster, eds., *The Art of Electronic Music* (New York, 1984).

56. Classical electronic music studios such as the Columbia-Princeton Center made music by "additive synthesis," that is, they added together sine waves to make up tones that were recorded on tape and from which a whole piece was spliced together.

57. Moog and Buchla synthesizers used "subtractive synthesis," which made it easier to produce complex sounds by taking a waveform already rich in overtones and filtering

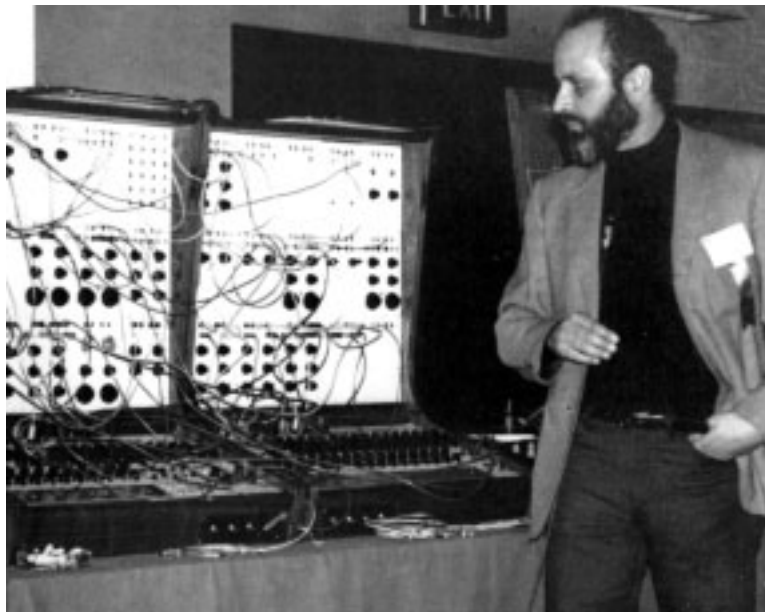

FIG. 2 Composer Morton Subotnick and Buchla 100 Synthesizer. (*Proceedings of the Audio Engineering Society* 18, no. 3 [June 1970], reproduced with permission.)

an oscillator to be varied according to its input voltage. The output from one oscillator could also control the frequency of a second oscillator, providing a form of vibrato. Feeding back voltages produced a great variety of sounds that moved dynamically in pitch and/or amplitude. Moog offered a monophonic keyboard and a ribbon controller (a continuous-resistance strip played by sliding the finger along it) as further variable sources of control voltages. In appearance the early synthesizers resembled analog telephone exchanges (fig. 1).

Buchla rejected the use of standard keyboards (fig. 2). Not wanting to be limited by the conventional twelve-tone scale, he favored an array of touch-sensitive plates to control various parameters and devices. In his view, the new source of sound—electronics—should not be controlled by an old technology that stemmed from hammers and strings. Buchla, himself an avant-garde artist, was interested in aleatoric composition. He incorporated a source of random control voltages into his design, and his instru-

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out some overtones. These synthesizers, unlike the RCA Mark II, also worked in real time. Moog and Buchla initially rejected the word "synthesizer," but in 1967 Moog's catalog featured for the first time his 900-series "Synthesizer"; see Pinch and Trocco, *Analog Days*.

ments allowed the user to set off complex chains of events that could feed back on each other.[58] He mainly sold his synthesizers to like-minded experimental composers; Vladimir Ussachevsky, for example, bought three, one for each of his identically equipped Columbia-Princeton studios.

Moog became the dominant manufacturer, because unlike Buchla he chose to make his synthesizer available to as many different sorts of musician as possible. His second customer was Eric Siday, a commercial musician who used the instrument for advertising jingles and "sound signatures."[59] Moog developed a very close relationship with Siday and other musicians to whom he sold instruments. He watched how they used his equipment, invited them to try out new instruments in his factory studio, and tinkered endlessly with his designs in response to their needs. His instruments' ease of use (everything was designed around a one-volt-per-octave standard) made them much more attractive to a greater range of musicians, and the keyboard, which featured increasingly in Moog advertising material, was an appealing feature. As Moog himself put it, "whenever someone wanted to take a picture, for some reason or other it looks good if you're playing a keyboard. People understand that then you're making music. You know [without it] you could be tuning in Russia!"[60] Most musicians were familiar with keyboards, and hence over time the synthesizer became a keyboard device. The influence of the wider culture and the dominant status of the piano and organ had left their mark.

Jon Weiss, a Moog studio musician who played both instruments, perceptively captured the difference between Moog and Buchla: "[Buchla] didn't want his machine to be a glorified electric organ. . . . His designs were wild and wonderful. Moog's were conservative, rigorous and well-controlled. . . . Everything under exact control of one-volt-per-octave, and everything will change exactly the same, and laying everything out in octaves, dividing twelve discrete steps, all that he carried through in the whole design of the machine."[61] Buchla saw himself as making instruments rather than machines: "I'm an instrument builder. . . . I don't build machines, I never have built a machine, I build only things that you play."[62] For Buchla, who refused to mass produce his synthesizers, each individual instrument had its own characteristics, idiosyncrasies, and ways of responding to human senses and touch.[63] By asserting the distinction be-

58. The best example of this effect is Morton Subotnick, *Silver Apples of the Moon* (Nonesuch, 1967).

59. Siday was famous for making the CBS sound logo and the percolating "burps" of coffee in a Maxwell House advertisement.

60. Robert Moog, interview by Trevor Pinch and Frank Trocco, Asheville, North Carolina, 5 June 1996.

61. Jon Weiss, interview by Trevor Pinch and Frank Trocco, Interlaken, New York, 8 May 1996.

62. Don Buchla, interview by Trevor Pinch, 4 April 1997.

63. Buchla did, however, license his designs to CBS for a short time around 1968–69.

tween machines and instruments, Buchla was drawing attention to what he considered the underlying values of genuine musical endeavors. The debate as to whether the synthesizer is a machine or a musical instrument is encapsulated in the differences between Moog and Buchla. Buchla is at the instrument end of the spectrum, stressing uncertainty, idiosyncrasy, the "wild and wonderful"; Moog is at the machine end, stressing control, reliability, and repeatability. This tension between "machine" and "instrument," and between the values and norms reflected in these different conceptions, resurfaces throughout the history of the synthesizer.

No one at this early stage foresaw a mass market. The first instruments were expensive (about the price of a small house) and were mainly purchased by wealthy composers and academic studios. They were also difficult to use (no instruction booklet or manual included) and extremely unstable: oscillators would drift out of tune, and a good sound obtained one day would vanish the next even with the same settings. Some of the waveforms produced by the synthesizer sounded like acoustic instruments, but the early users were more interested in exploring new sounds than in trying to emulate conventional instruments. Jon Weiss, who had been trained as a violinist, commented that "as far as I'm concerned even when you are using the modern digital generation stuff, the sounds are never as good as the original acoustic sounds, they are so many degrees more complex. I figured what's the point of that—if you wanted something to sound like a French horn then play a French horn. . . . Why use this machine to do just that?"[64] Such users preferred the "Moog to be Moog" and saw the synthesizer as an instrument in its own right.[65]

It was psychedelic musicians, with their interest in sound washes and such sonic effects as feedback, flanging, and echo, and their fascination with unusual instruments like the sitar, mellotron, and theremin, who pioneered the synthesizer. Buchla, who was friends with the Grateful Dead and part of the developing counterculture, first realized the potential of the synthesizer in this new form of music. In 1966 he was at the controls of his synthesizer for an early "happening" (the Trips Festival, held in the heart of Haight-Ashbury in January). But the Moog synthesizer was easier to use, and it became the instrument of choice in psychedelic rock after Moog's West Coast salesman, Paul Beaver, sold Moogs to several well-known groups at the famous 1967 Monterey Pop Festival. The Doors and the Byrds used Moog synthesizers on some of their early recordings, as did the Beatles on some of their later albums.[66] Buchla continued to sell small numbers of synthesizers, mainly to academic studios, but never reached the mass market.

64. Weiss interview.

65. David Borden, interview by Trevor Pinch and Frank Trocco, Ithaca, New York, 3 May 1996.

66. See, for example, the Doors, *Strange Days* (Electra, 1967); the Byrds, *The Notorious Byrd Brothers* (Warner Brothers, 1967); and the Beatles, *Abbey Road* (Apple, 1969).

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In 1968 Moog realized that the synthesizer and his newly designed low-pass filter (the only device he patented) could have an even greater reach among musicians.[67] Moog himself observed the effect of his unique bass sound on musicians during a Simon and Garfunkel recording session.[68] "One guy was playing a bass and he stops and he listens, and listens. He turned white as a sheet."[69] The synthesizer didn't just sound like an acoustic or electric bass; with its fat, resonant, squelchy sound it sounded better. Moog liked to tell this story at his factory to let people know that he felt that at last he was "getting somewhere." The Moog was starting to find a home among musicians at large, and session musicians were some of the first to see the threat that the synthesizer posed to their livelihoods.[70]

Moog's long-sought-after breakthrough came in the fall of 1968. One of his first customers was a young composer of electronic music from the Columbia-Princeton studio, Walter Carlos.[71] Carlos, who had degrees in physics and music, formed a close relationship with Moog and quickly became his sternest critic, suggesting many improvements and refinements to the instrument. In return he received custom-built modules. Carlos was also a skilled studio engineer, and he teamed up with Rachel Elkind to produce one of the recording sensations of 1968, *Switched-On Bach*.[72] The album, which quickly went platinum and remains one of the best-selling "classical" records of all time, is a compilation of Bach's "greatest hits" performed on the Moog synthesizer. Carlos, with his skillful use of tape dubs and splices, made the Bach pieces come alive, with timbres based on acoustic instruments but clearly different and "electronic." Described as "one of the great feats in the history of 'keyboard' performance," *Switched-On Bach* won many plaudits.[73]

Paradoxically, Carlos's achievement was "acclaimed as real music," despite being almost impossible to perform live.[74] Early synthesizers were effectively studio-only instruments, as setting up the patches and taping

67. Moog's low-pass filter was known as a "ladder filter" after the ladder of transistors in the circuit. See Pinch and Trocco, *Analog Days* (n. 4 above), for details.

68. Simon and Garfunkel, "Save the Life of a Child," *Bookends* (CBS, 1968).

69. Moog interview (n. 61 above).

70. That threat was taken up the musicians' union, the American Federation of Musicians; see Pinch and Trocco, *Analog Days*.

71. Walter Carlos later underwent a sex change operation and became known as Wendy Carlos.

72. Walter Carlos, *Switched-On Bach* (Columbia, 1968).

73. Glenn Gould, "More Notes by Glenn Gould and Wendy Carlos on the Well-Tempered Synthesizer," in *Switched-On Boxed Set: Original Notes*, liner notes to *Switched-On Boxed Set* (Columbia, 1999), 20. This is a reissue on CD of the original 1968 Columbia recording and includes original liner notes as well as new liner notes. Gould himself earlier had a controversial but hugely successful classical hit with *The Goldberg Variations* (Columbia, 1956).

74. Robert Moog, "Bob Moog Comments," in *Switched-On Boxed Set: New Notes*, liner notes to *Switched-On Boxed Set* (Columbia, 1999), 8.

the sounds took inordinate amounts of time. However, a small number of pioneering musicians began to explore the synthesizer's potential for live performance.

David Borden (another of Moog's studio musicians) founded the first live synthesizer ensemble, Mother Mallard's Portable Masterpiece Company, in 1969. The band's music could be described as a form of electronic minimalism, and they rehearsed in a way unique in the history of music: they practiced the labyrinth patch changes their music required in silence. Even so, the changes took so long that to keep audiences interested they showed cartoons between pieces. The early synthesizer performers discovered in practice what worked and what did not. For example, the Japanese synthesist Tomita, after the success of his synthesized rendition of Debussy on a modular Moog, set off on a tour of Europe using the best sound system available (borrowed from Pink Floyd). "I thought it would be a dream come true if my music could be played in such halls with good audio equipment. . . . But really, a live performance of this genre of music is absolutely impossible. So I was playing simple sounds on the synthesizer on the spot, while the rest of the music was coming through a four-channel tape system. . . . It embarrasses me a lot."[75] The concerts did not meet the audiences' demands for a proper live performance.

The success of *Switched-On Bach* made it increasingly clear that the Moog synthesizer had found a home in popular music. But the Moog Company continued to experience problems. The company saw a huge increase in orders in 1968–69, but this was quickly followed by a downturn, as the market became glutted. At the same time, the recording industry was discovering that Carlos's feat was hard to replicate. Rather than ride the wave of success, Moog found himself facing bankruptcy in the early 1970s.

Moog and his engineers set to work developing a new instrument. They came up with one of the most significant milestones in synthesizer history: the first portable keyboard, the Minimoog.[76] This instrument (fig. 3) had some of the fabled sound of the modular Moog (it used the same patented filter design), but, being portable and hardwired, with modules connected together in fixed configurations, it was easier to use. It had much more stable oscillators, and its forty-three knobs and switches could be set up according to "sound charts" to reproduce desired sounds (including those of some acoustic instruments). The instrument was also significantly cheaper; at around one thousand dollars, members of pop and rock groups could (just) afford it.[77] A "pitch wheel" for pitch bending facilitated the piercing

75. Interview with Tomita, in Darter and Armbruster (n. 56 above), 159.

76. Robert Moog was awarded the Polar Prize for music in 2001 for his invention of the Minimoog. The Polar Prize is awarded annually by the King of Sweden and is regarded by many as a mini-Nobel Prize for music.

77. This was still expensive for amateur and semiprofessional musicians; a thousand

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FIG. 3 1970 preproduction Minimoog Model D. (Photo by Roger Luther, courtesy of MoogArchives.com.)

monophonic solos that enabled keyboard players to take their place alongside electric guitarists as the new virtuosos of rock.

The Minimoog's yowling sound became an essential part of "progressive rock," with synthesizer virtuosos like Keith Emerson of Emerson, Lake, and Palmer and Rick Wakeman of Yes leading a second British invasion in the early 1970s (both Wakeman and Emerson had their sounds immortalized in the Minimoog sound charts). It was the first synthesizer to have mass appeal and was sold in a new way, through retail music stores, thus laying the foundation for a retail market in synthesizers.[78] Unfortunately, the success of the Minimoog (it had lifetime sales of twelve thousand units) came too late for Moog, and in 1971 he was forced to sell his business.

Although it is an analog instrument, the Minimoog was an important precursor to digital instruments. It shares their portability, ease of use, reliability, built-in keyboard, and hardwired sound. The Minimoog sound charts provided the first standardized and reproducible menus of sounds.

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dollars at the time could have bought a used van, another important piece of rock group equipment.

78. Trevor Pinch, "How the Minimoog Was Sold to Rock 'n' Roll," in *How Users Matter: The Co-Construction of Users and Technologies,* ed. Nelly Oudshoorn and Trevor Pinch (Cambridge, Mass., in press).

The development of the Minimoog heightened the tension in the argument over whether the synthesizer was an instrument or a machine. Moog and his engineers treated the imprecisions of the modular instruments as something to be corrected in the course of the instrument's technical evolution. For some musicians, however, the imprecisions and technical failures were actually positive attributes of the early instruments. As Jon Weiss put it, in talking about the early Moogs: "[It] was not as accurate as all the engineers wanted it to be. . . . That was what was so wonderful about the machine, in that sense it was an instrument, it wasn't a machine. A machine would have created no inaccuracies. . . . Accuracy like that doesn't exist in our lives, nature is never accurate, there are always weird concussions of sound waves, and overlapping and so on."[79] Weiss' appeal to "weird concussions of sound waves" and the inaccuracies of nature is the same desire for "uncertainty re-controlled," for mysteriousness "trapped," that emerged earlier in the debate over noise instruments.[80]

Musicians delighted in producing music on their Minimoogs that defied the engineers' expectations. One early user was the legendary black jazz musician Sun Ra, who was given one of the first prototypes. Weiss went to a concert given by Sun Ra in New York City to see how the machine was bearing up and was amazed to discover that "he had taken this synthesizer and I don't know what he had done to it . . . total inharmonic distortion . . . but he created these absolutely out of this world sounds, that the engineers could never have anticipated . . . fabulous."[81] Don Preston, who played Minimoog for Frank Zappa and the Mothers of Invention, remarked, "I did a solo on one of the Mothers' albums and Paul Beaver played it for Bob Moog, and he listened to it and he said, 'That's impossible, you can't do that on a Minimoog.' I always enjoyed that comment."[82] Brian Eno, who in the early 1970s pioneered the use of another early portable synthesizer, the VCS3 made by Electronic Music Studios of London, also alludes to the importance of inaccuracies in the machine. One module of his VCS3 was broken, but he preferred the sound the instrument made in that condition. Whenever he had his synthesizer serv-

79. Weiss interview (n. 62 above).

80. Something similar happened with feedback noise in early electric guitars. At first it was seen as something uncontrolled and unwanted. From the fifties and sixties onward, however, musicians (Jimi Hendrix being the most famous) started to use "controlled feedback" within their music, thus reconceptualizing noise as music. See McSwain (n. 55 above) and Waksman (n. 3 above).

81. Weiss interview. Examples of Sun Ra using the Minimoog can be found on *My Brother the Wind* (Saturn, 1969) and *My Brother the Wind, Volume 2* (Saturn, 1970). For a biography of this remarkable musician, see John F. Szwed, *Space Is the Place: The Lives and Times of Sun Ra* (New York, 1998).

82. Don Preston, interview by Trevor Pinch and Frank Trocco, Los Angeles, 5 April 1997. The solo Preston is referring to here is "Waka/Jawaka," on *Waka/Jawaka*, Frank Zappa and the Mothers of Invention (Bizarre, 1972).

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iced, then, he had to leave a note reminding the technician that the module was not to be repaired![83]

We do not want to suggest that the views of musicians like Sun Ra, Don Preston, and Brian Eno, which are similar to the views of the futurists about sound, are anything other than those of a minority. They form, however, an important critique of the predominant move toward making the synthesizer as precise as possible in terms of its sound-generating possibilities. The importance of the musician being able to exercise control, so that, as Jon Weiss put it, the synthesizer "took on the characteristics of whoever was using it," reminds us again of the value of personal achievement.[84] Another way that control becomes important is through the interface. For some synthesists the analog interface of "knobs and wires" offered better personal control than the digital menus and buttons of the later instruments. Brian Kehew, a young musician who plays old analog synthesizers in the analog revivalist band Moog Cookbook, reflects: "I really thought the control and the sounds of the analog synthesizer was much better than the new keyboards that had one slider, or a data entry. I thought that was a horrible way to do anything."[85] Such critiques are at the core of the current analog revival, with vintage synthesizers commanding record prices and reproductions being manufactured for a variety of forms of popular music, including pop, rock, rap, and techno.[86]

By the mid-1970s, as the synthesizer became more like an electronic organ with a polyphonic keyboard and preset sounds, the era of exploring new sounds was coming to an end. By the time the first commercially successful digital instrument, the Yamaha DX7 (lifetime sales of two hundred thousand), appeared in 1983 with an astonishing range of presets (including most acoustic instrument sounds), synthesizers were too complicated for most users to program themselves, and a separate cottage industry of "plug in" sound cards developed. The adoption of the MIDI (Musical Instrument Digital Interface) standard in 1982, enabling synthesizers from different manufacturers to be connected together and/or connected to personal computers, and the subsequent waves of digital synthesizers marked a geographical shift in the industry, with Japanese companies like Yamaha, Roland, and Korg becoming the dominant players in this new global industry. In the 1990s the Japanese company Casio sold millions of its keyboards for home entertainment. The dissemination of the synthesizer during the 1980s and 1990s reflected the same norms of democratized leisure apparent in the success of the player piano.

83. Interview with Brian Eno, in Darter and Armbruster (n. 56 above), 220.

84. Weiss interview.

85. Brian Kehew, interview by Trevor Pinch, Los Angeles, 20 July 2000.

86. On the analog revival, see Mark Vail, ed., *Vintage Synthesizers*, 2nd ed. (San Francisco, 2001), and Pinch and Trocco, *Analog Days* (n. 4 above).

It is routine today to hear electronic scores and sound effects in movies, television shows, and video games. Computer sound cards are directly descended from the Yamaha DX7 (the patent held on the DX7 was for many years Stanford University's top-earning intellectual property), and synthesizers now built into integrated circuits lurk in devices ranging from video games to children's books to car alarms. Synthesizers, including drum machines, can be found everywhere in almost every musical genre—especially techno.[87]

There is no doubt that the synthesizer is a unique musical instrument because of its capacity to reproduce the sound of other instruments. But interestingly enough, many synthesists themselves reject the idea that it can actually replace musicians. In the late 1970s and early 1980s, with the growing power of synthesizers to emulate acoustic instruments threatening musicians' livelihoods, synthesists started to debate what the synthesizer could and could not do. Perhaps surprisingly, skeptics appealed again to the same norms concerning the nature of art that critics of earlier technological innovations had cited. As Michael Boddicker commented: "They [the union] think I can replace a trumpet player . . . who's been playing for twenty or thirty years on just that instrument. They know all the styles indigenous to that instrument. . . . I would have to live as a trumpet player for twenty years like those cats to have that much knowledge."[88] This remark draws a boundary in terms of musicianship; what counts is not being able to make the sound of a trumpet but being able to play all the different trumpet styles. Such an argument against the encroachment of machines relies on irredeemable human features of musicianship that cannot be captured by machines. It is similar in form to the arguments made by critics of artificial intelligence.[89]

It is in the area of performance that the synthesizer is often seen as lacking the qualities necessary to produce proper musical art. John Chowning, a percussionist and engineer (and the inventor of the digital algorithms used in the Yamaha DX7) makes the point this way: "There's a special relationship between performance and the literature and the players and their instruments that is not going to be violated, no matter what kind of a futurist view one might hear. . . . The commercial view of the effect of synthesis [in replacing conventional instruments] I just think is absolutely beyond

87. On the development of the Yamaha DX7, see Bob Johnstone, "The Sound of One Chip Clapping," in *We Were Burning: Japanese Entrepreneurs and the Forging of the Electronic Age* (New York, 1998).

88. Interview with Michael Boddicker, in Darter and Armbruster, 246.

89. Hubert L. Dreyfus, *What Computers Can't Do: A Critique of Artificial Reason* (New York, 1972), and Harry M. Collins, *Artificial Experts: Social Knowledge and Intelligent Machines* (Cambridge, Mass., 1990). Interestingly, in the case of artificial intelligence the arguments are made by outsiders—philosophers and sociologists inspired by phenomenology.

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belief. It's bullshit."[90] Human control over performance and interpretation sets the boundary between what synthesizers can and cannot do. Similarly, Klaus Schulze of Tangerine Dream remarks, in a comment reminiscent of the earlier criticisms of the player piano: "Computers will never replace the human touch in music. . . . Even if you could program a computer to add that human variable element, it wouldn't be the same. Otherwise, you could just program a symphony and it would always sound the same."[91]

Of course, listening culture is not itself static. As Emily Thompson has shown, at the start of the twentieth century audiences had to learn to listen to the music they experienced in the new concert halls in new ways.[92] Similarly, with listeners constantly exposed to synthesized sounds, as they are in movies and with techno music, their expectations for what counts as credible sound, and hence what counts as musicianship, will also change. Indeed, as virtuoso DJs take center stage in techno and dance music, we are reminded that what counts as a "musician" also can change.

Stability and Change

One aspect of this story that deserves attention is the presence of stability in the midst of change. Indeed, it would appear that elements of musical culture are remarkably persistent. Part of the explanation for this may lie in the musical institutions that dominate Western societies—schools, conservatories, concert halls, critics, and so on—and reproduce these values.[93] It is also clear that within musical culture the relationship between producers and users of new, machine-like instruments has been extremely close. Instrument makers often were (amateur) musicians, composers, or artists themselves, whether or not they also worked with engineers.[94] Because of this, values central to musical culture have helped inform the production, acceptance, and transformation of new technologies. Within the context of musical culture, especially the world of composing and live, onstage performance, personal achievement has been of enduring importance: machines or machine-like instruments have been incorporated in ways that permit personal achievement to remain visible and audible.

At the same time, again because of the importance of personal achievement, the control over sound and interpretation that machines have

90. Interview with John Chowning, in Darter and Armbruster (n. 56 above), 109.

91. Interview with Klaus Schulze, in Darter and Armbruster, 185.

92. Thompson, *The Soundscape of Modernity* (n. 4 above).

93. For the importance of tradition resulting from, for instance, the "interminable cycle of teacher-learner-teacher" in private tutoring, "reinforced and encouraged in the curricula of most music institutions," see Bruce Pennycook, "Live Electroacoustic Music: Old Problems, New Solutions," *Journal of New Music Research* 26 (1997): 70–95, at 72.

94. Moog and Buchla were both amateur musicians and worked closely with other musicians. See Pinch and Trocco, *Analog Days* (n. 4 above).

enabled has also been embraced. Moreover, machines have been incorporated in the contexts of musical performances and compositions by blending old values with new, as in "recreation for all plus personal achievement" or "uncertainty re-controlled." This has paradoxically served to sometimes strengthen the norm of personal achievement.

There is little question that the synthesizer has changed the face of much popular music, or that it has put some musicians, particularly session musicians in New York and Los Angeles, out of work. Indeed, the role of the profit motive is notably understated in this article because of our focus on art versus machine. Work displacement and the synthesizer is a topic that merits its own study. But, as always, the story of technical change and work is a complicated one, with new opportunities opening up as well. The mass-production of affordable versions of these instruments and the consequent democratization of musical opportunity, so to speak, has been an important development, too. Musicians have, however, been able to keep some areas of musicianship from the encroaching machines by defining machine-instruments in such a manner that the artistic dimension of their practice can be kept alive.

Within the world of composing and onstage performance, the value ascribed to skill has restricted the role of the machine. Even where the threat of the machine seems greatest, in digital sampling, the aesthetic system founded on control and personal achievement has not vanished but rather been reworked.[95] Techno bands, too, have found that in the domain of live performance, audiences expect some displays of virtuosity. New instruments are important because they allow people to do new things in new ways. But acceptance seems to depend on an alignment between old values and new practices. Old norms and values, it seems, die hard.

95. On sampling, see Andrew Goodwin, "Sample and Hold: Pop Music in the Digital Age of Reproduction," *Critical Quarterly* 30, no. 3 (1988): 34–49.