

"Emulating Sound. What Synthesizers can and can't do: Explorations In the Social Construction of Sound"

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The topic of this chapter, the social construction of sound, is one aspect of what I increasingly see as a new field, "Sound Studies". Sound Studies extends the insights of Science and Technology Studies to the arena of music, sound, noise and silence.¹ The materiality of sound, its embeddedness not only in history, society and culture but also in science and technology and its machines and ways of knowing and interacting, is a topic which I think is not yet addressed sufficiently by other fields like musicology and the history and sociology of music.²

I want to discuss the emulation of sound in the history of the electronic music synthesizer as an element in the social construction of sound. My particular focus is on the period 1964-1975 when the best known early synthesizer, the Moog Synthesizer (see figure 1), was developed and manufactured. This modular, transistorized, voltage-controlled device was much smaller than the existing room-sized tube synthesizers such as the RCA Mark II (built in 1958) housed at the Columbia-Princeton Electronic Music Studio.

The synthesizer is one of the few successful innovations in the history of musical instruments. Although the history of musical instruments is littered with all sorts of inventions very few of them get to be taken up in widespread use - that is move from being inventions to innovations. Indeed arguably the last successful new instrument before the synthesizer was the saxophone invented by Adolphe Antoine Sax in 1840. Of course there have been electronic instruments before the synthesizer which have made some impact like the massive 200 tons telharmonium, the Theremin, the Trautonium and the Ondes Martenot (still used in classical repertoire in France.³ One should note here also the successes of the Hammond Organ (which, like the telharmonium, uses a electro-mechanical source of sound - the spinning tone wheel) which was very popular in churches in the 1950s and then later as a pop instrument.⁴ The electric guitar is of course a massively successful instrument - the addition to the guitar of

amplification, feedback and effects pedals transformed it into a new instrument.⁵ The synthesizer is, however, a more radical innovation because it uses a completely new source of sound, electronics. Indeed arguably the synthesizer presents us with more than just a case of a successful musical innovation it is also a crucial point in the revolution in the very way that music is produced and consumed - a revolution that is still underway. The synthesizer and closely aligned technologies like the digital sampler when coupled with the digital computer and internet allow all sorts of new possibilities for making, manipulating, storing, and moving music around the world. It is now possible to bypass the recording studio completely and music can be made as a process of distributed cognition across space and time. Synthesizers now built into sound chips are everywhere. Indeed for many years Stanford University's biggest earning patent was one held on a form of synthesizer, FM synthesis, which formed the guts of the Yamaha DX7 synthesizer - the first commercially successful digital synthesizer - and later generations of computer sound cards like "Sound Blaster".⁶ Today Japanese Multinational Corporations like Roland, Yamaha, Korg and Casio dominate the market for synthesizers. They are today used in every genre of music and can be found in games, children's books and in novelty children instruments.

The role of the Moog Synthesizer in particular is increasingly being recognized. In 2001 Bob Moog was awarded the Polar Prize for music, for his 1970 invention of the Minimoog synthesizer, a portable keyboard instrument (see figure 2). And in 2002 the Moog Synthesizer and the Apple Computer received Grammy awards for their contributions to the music industry. I have just completed a book on the history and impact of the synthesizer.⁷ The book is mainly based upon interviews conducted with engineers and musicians

If one looks at the history of the Moog synthesizer one finds the following key events which I show here on a timeline:

Timeline

1963: Moog meets experimental composer Herb Deutsch. Moog builds prototype voltage-controlled modules.

1964: Moog attends Audio Engineering Society meeting in New York and sells his first modules.

1964-7: Moog develops more modules and adopts One-Volt-Per-Octave

Standard and keyboard controller.

1966: The Beach Boys release "Good Vibrations" which uses electronic sound of Theremin.

1967: Moog's first sales catalog featuring standardized 900 series "SYNTHESIZER".

1967: Moog hires sales reps in NYC and LA.

1967: Moog synthesizers demonstrated and sold at Monterey Pops festival. Used in making the psychedelic music of Byrds, Doors and Beatles.

1968: Wendy Carlos releases Switched-On Bach.

1968-69: Hundreds of "artists" release copycat Switched-On records on Moog Synthesizers - e.g. Switched-On Santa, Switched-On Baccarach, etc.

1970: Emerson Lake and Palmer release, "Lucky Man".

1970: Minimoog produced.

1970: Synthesizers sold in retail music stores and demonstrated at music trade shows.

1971: Moog company sold and moves to Buffalo.

1970s: ARP of Boston and EMS of London make synthesizers used by major recording artists like Pete Townshend, Stevie Wonder and Pink Floyd. Synthesizers used for many movies including Star Wars, Close Encounters, The Exorcist, Apocalypse Now.

1983: Yamaha DX7, the first commercially successful digital synthesizer, produced.

1980s-today: Market dominated by Japanese multinationals - Roland, Korg, Yamaha and Casio. Old analog synthesizers made by Roland used in techno and rave music.

Today, synthesizers are digital machines, they invariably are portable keyboard instruments, with a menu of "stored sounds", "sound effects" or "factory sounds" and many of these sounds include acoustic instruments like snare drum, marimba, harpsichord, clarinet etc; they also include sounds of earlier electronic instruments such as the Hammond B3 organ, or the Moog Synthesizer (often referred to as the M sound) and they include "natural" sound effects - like "handclaps" or "thunder", and "synthetic" "made up sounds" sounds which are given new names which must try and capture the sound - on my daughter's Korg 707 synthesizer, these sounds include "Mr Analog", and "Laser Synth". As well as sounds there are often whole accompaniments with different combinations of instruments in different beats. One of the latest developments is software companies who produce digital emulations of old analog synthesizers. You can buy software which

not only emulates the sounds of old synthesizers but even emulates the knobs and wires (you still have to use the mouse to set the wires and remove patch cords).

Some Important Changes in Synthesizers

Table (1)

Some Rough Numbers of Synthesizers Sold

Moog and Buchla Modular (lifetime): few hundreds

Minimoog (lifetime): 12,000

Yamaha DX 7 (1983-86): 200,000

Casios (1980-1990): 15,000,000

As can be seen from Table (1) the synthesizer market has expanded rapidly from 1963 to present days. The prices of the instruments have also fallen dramatically. Modular Moogs cost about \$15,000 in 1968 - the price of a small house. Today you can buy a Casio for under \$100.

It is difficult to comprehend now, but back in 1963 people were hardly ever exposed to electronic sounds. The main electronic sounds available were the Theremin (and Trautonium and Ondes Martneot) used in Hollywood movies (and a very few classical performances), and the experimental and avant garde music of composers like Cage and Stockhausen. But today we are saturated with electronic sounds (from films, TV, popular and dance music and electronic devices). It's almost impossible to escape.

Table (2)

Where Can you See and buy synthesizers?

1963-1970: Moogs sold direct from the company (2 sales reps). Demonstrated at Audio Engineering Society.

1970-today Korg, Yamaha, Roland sold in retail music stores (vast sales networks). Demonstrated at NAMM (National Association of Music Merchants) or Frankfurt Music Messe.

Table (3)

Transformation in Architecture of Sound

1963: Knobs and Wires - open architecture of sound.

Today: Digital interfaces - prepackaged sounds.

Other interesting transformations have happened including where synthesizers are bought and sold (see Table (2)) and in the

architecture of sound (see Table (3)). Modular Moogs had open architecture, you could connect patches up in infinitely flexible ways to make many, many different sorts of sounds. Musicians at the time would say that the tape recorder was your "best friend". Emulation of acoustic instruments was difficult to do, not very convincing, and rarely attempted. Today most synthesizers play prepackaged sounds - including a range of acoustic instruments and emulations of earlier electronic instruments.

The Minimoog was an important way station in these changes - it was the first instrument sold in retail music stores and was hardwired and had "standard sounds" which were described for the first time with "**sound charts**" (invented by a Moog salesman - David Van Koevering). By the time of the first digital synthesizer, the Yamaha DX7 in 1983, users were not programming their own sounds. A separate cottage industry for programming sound cards had arisen.⁸

Today there is an analog revival: old analog machine, known as "Vintage Synthesizers", command top prices, companies are still manufacturing and selling some old analog machines, and these analog machines are used in a variety of genres, like pop, rock, rap, and rave.⁹ Part of the Analog Revival is nostalgia but also there is something else going on - some musicians prefer the old interface of "knobs and wires" (most modern digital synthesizers use digital menus and LEDs), also they feel that modern synthesizers don't have such an interesting range of sounds.¹⁰ They miss the sounds "between the knobs" as it were. They often use digital samplers to sample the sound of old analog synthesizers.

In order to understand these changes and how the synthesizer became a very special sort of instrument, one that could emulate or imitate other instruments, we need to delve a little more into the design of Moog's synthesizer.

Moog and Music

The spur to Moog's invention of the synthesizer was a 1963 chance meeting with Herb Deutsch, an avant-garde electronic music composer. Deutsch worked in the standard way at the time with oscillators and tape recorders - the oscillators were used as sources of sound and Deutsch laboriously assembled electronic music by recording such sounds and splicing the tapes together.

Deutch told Moog that he and other composers wanted a more portable and affordable studio on which to make such compositions. Also making electronic music was a time-consuming business and it would be great if there was some way to make the process more dynamic - as Deutsch put it a way "so sounds could move".¹¹ Moog set to work to help Deutsch.

Moog's goal in developing the synthesizer was not just to produce an electronic box that produced sounds - he wanted to make a musical instrument. He had learnt piano as a kid and built Theremins; he came out of the radio hobbyist tradition working in his father's basement workshop (his father was an engineer for Con Edison). With a degree in electrical engineering at Columbia he knew also about developments in transistors. When he encountered Deutsch in 1963 he knew how to make certain sorts of sounds and how to control them. He had worked with sound and knew the shapes of different waveforms and the sounds they made. He was an inveterate tinkerer. The musicians played the instruments, but the engineers played the circuits. To play them well they needed to have good eyes, ears and hands. Different instruments and senses combined in the way Moog worked. With the aid of an oscilloscope he used his eyes to see the shape of the waveform, with the aid of a loudspeaker he used his ears to hear the sound of the waveform, and with the aid of a voltmeter he used his hands to tinker with the circuit producing the waveform.

Moog knew that cheap silicon transistors had become widely available, replacing the bulky and expensive vacuum tubes. One newly introduced form of the silicon transistor was of particular interest to him. It had an exponential (logarithmic) relationship between its input voltage and output current over the frequency range of musical interest (several octaves). Exponentially varying properties are common in music; for instance, the frequency of the tones in a scale in the lower range increases exponentially in the higher registers (an octave increase is a doubling of pitch), as does loudness which is measured by the exponential decibel scale. So Moog thought that he might be able to make something musically useful if he used these new transistors.

Moog now had a key insight - voltage control. He built oscillators and rather than varying the pitch of an oscillator manually by turning a knob or, as in the case of the Theremin, by moving a

hand, he could make the pitch change electrically by using a "control voltage" to vary it. A larger voltage fed into the oscillator as a "control" would produce a higher pitch. This meant that an oscillator could be swept through its total pitch range (several octaves) simply by increasing the voltage. Similarly a voltage controlled amplifier could be swept through the complete dynamic range of human hearing. By building "exponential converter" circuits into his devices - circuits which converted a linearly varying parameter like a voltage into an exponentially varying parameter like frequency or intensity - Moog made these control voltages musically useful. It enabled him to design all his modules around a single standard - the volt-per-octave standard - such that a change of a control input of one volt produced a change in the output pitch of one octave.¹² Some form of the volt-per-octave standard was adopted by other synthesizer manufactures in the 70s like ARP and EMS."

At this stage what Moog had built didn't look very impressive - a few transistors wired together, along with a couple of potentiometers. Moog:¹⁴

I had this little breadboard with three different circuits on it: two voltage control oscillators and a voltage control amplifier. They weren't accurate and they weren't a lot of things, but they had the advantage of voltage control. You could change the pitch of one oscillator with the other oscillator. You could change the loudness.

Moog compared that breadboard to a hot rod, "It's an electronic circuit that's all hanging out so you can get in and change things quickly. So it's like a hot rod without any body on - everything is sticking out."¹⁵

Having two voltage controlled oscillators as opposed to one doesn't sound like very much, but it was the breakthrough. The two oscillators were designed such that the output from one (itself a varying voltage) could be used to control the pitch of the other or the loudness of the signals via the voltage controlled amplifier. By adding a slowly varying sine wave as an input to an oscillator a vibrato effect could be obtained. Feeding the same input into a voltage controlled amplifier could produce a tremolo effect. But this was only the start. Many, many more interesting sonic effects could be obtained by experimenting and feeding back signals which in turn could be used as new controls. This was the secret to making sounds move. The hot rod now was ready to roar.

Moog describes what happen when Deutsch came to visit him in remote Trumansburg where he had his first shop:¹⁶

Herb, when he saw these things sorta went through the roof. I mean he took this and he went down in the basement where we had a little table set up and he started putting music together. Then it was my turn for my head to blow. I still remember, the door was open, we didn't have air conditioning or anything like that, it was late Spring and people would walk by, you know, if they would hear something, they would stand there, they'd listen and they'd shake their heads. You know they'd listen again - what is this weird shit coming out of the basement?

The "weird shit" was historic. It was the first sounds from the very first Moog synthesizer.

In terms of making a musical instrument Moog had embedded a key design concept into his instrument. By thinking in terms of octaves Moog had embedded an element of conventional musical culture into his machine: music was to be thought of in terms of intervals and octaves. Even more crucially Moog and Deutsch soon wired up an organ keyboard as a controller - with the exponential converter circuits in his oscillators the linear varying voltage output from a chain of resistors and switches could be converted into a useful musical control - a monophonic keyboard.

This was a much more immediate way of working with electronic music than in a classical studio - the potentiometers and patch wires provided immediate changes in the timbre of the sound in **real time** in dynamic ways. With just a twist of the knob or the plugging in of a wire you could cover the full frequency of human hearing and the timbral qualities of these sounds could be varied at a much faster rate and with much more dramatic effects than had proved possible before.

The importance of thinking about how sound was produced in conventional musical instruments was evident in Moog's next invention - the "envelope generator", which later became a standard device on all synthesizers. An envelope generator allows the loudness of sound to be structured or contoured to produce, say, the effect of a string being plucked, where the loudness builds up rapidly and then decays away slowly. Deutsch:¹⁷

I said, "It would be great if we could articulate the instrument," and Bob said, "What do you mean?" I said..."You

play a key, it was on and you lift your finger off and it was off."...And he thought about it and he said, "Okay, that's easy enough to do." So he said, "Listen, do me a favor. Go across the street to the hardware store and buy me a doorbell button." So I went across the street and I bought a doorbell button for 35 cents...and he took out a yellow piece of paper and he started throwing a few formulas and things down...

Moog had found a way using a doorbell and a capacitor to store and slowly release a voltage produced at the same time as hitting a key. He soon refined this early design so as to avoid the need to push a separate button with every key press. He put two switches on every key; one to produce the control voltage and the other to trigger the envelope generator. This envelope shaper could be used to contour the sound's amplitude.

The Moog instrument was based on a process known as subtractive synthesis. Moog's sources of sound, for instance, oscillators, produced complex waveforms, such as sawtooth, and square wave which had many overtones. By using devices like filters (which could remove a certain range of frequencies) you could filter these overtones to make the sounds even more sonically interesting. Most classical studios worked with additive synthesis - since any sound can by Fourier analysis be broken down into sine waves of different frequencies (a fundamental and overtones), it should be possible to assemble any sound by adding together sine waves.

It was noted early on that some of the waveforms the Moog synthesizer produced sounded a bit like acoustic instruments. For instance, the sawtooth waveform makes a bright, full, brassy sound; a triangle waveform sounds much thinner and purer, like a flute; and the pulse wave produces a nasal, "reedy" sound. However, the early composers and musicians who used Moog's instrument were ambiguous about attempting to emulate conventional instruments with this new instrument. Many electronic music composers (like Stockhausen, Ussachevsky and Cage) saw little point in trying to make sounds which imitated or emulated acoustic instruments. They thought that electronic music should develop its own aesthetics working with this radical new source of sound.

Buchla's Radical Vision

The interesting thing in terms of the development of the synthesizer is that there was another pioneer electronic music

inventor, Don Buchla, who worked on the West Coast at the same time as Moog who was much more influenced by this avant-garde tradition. Buchla, like Moog, came from the hobbyist tradition and like Moog had a background in electronic engineering (at Berkeley). He met avant-garde music composers Mort Subotnick and Ramon Sender at precisely the same time that Moog met Deutsch. Sender and Subotnick had just founded the San Francisco Tape Music Center and wanted to use electronics to make a more portable and affordable electronic music studio. The design that Buchla came up with independently from Moog's was very similar: it was modular, used patch wires and voltage control - but there was one crucial difference - Buchla rejected the standard keyboard altogether and did not build oscillators that followed the volt-per-octave standard (see Figure 3). (Buchla also invented a new device, which became known as the "sequencer" which was a means of repeatably generating a sequence of different voltages, and thus a way of avoiding tape splicing altogether).¹⁸

Buchla reasoned that here was a new source of sound - electronics - but why be stymied by an old technology based upon hammers and wires. He wanted something more imaginative as a controller that would better enable the performer to connect to the new source of sound. He designed arrays of touch-sensitive metal pads housed in wooden boxes that he called the "Kinesthetic Input Ports". Although these pads could, with extreme difficulty, be tuned to play the twelve-note chromatic scale, Buchla's whole design philosophy was to get away from the standard keyboard.

His attitude was shaped by the avant-garde composers he met at the Tape Center. John Cage and his collaborator David Tudor were exactly the sort of artists with whom Buchla identified. Cage used Buchla's touch pads to control one of his favorite pieces of equipment, the voltage controlled FM radio receiver (which he used as a source of electronic sound for musical performance). Each pad was used to control a different station. Buchla's first ever sale was in fact to David Tudor for whom he designed a set of five circular pads that when coupled with the appropriate module could move sound around a space, from speaker to speaker.

In Buchla's vision of a keyboardless synthesizer the operator would be stimulated to explore the new sounds of which the new instrument was capable:¹⁹

A keyboard is dictatorial. When you've got a black and white

keyboard there it's hard to play anything but keyboard music. And when's there not a black and white keyboard you get into the knobs and the wires and the interconnections and the timbres, and you get involved in many other aspects of the music, and it's a far more experimental way. It's appealing to fewer people but it's more exciting.

Electronic music composers like Vladimir Ussachevsky found Buchla's way of working more appealing than Moog's and another of Buchla's earliest orders was for three identical systems for each of the three studios that Ussachevsky ran at the Columbia-Princeton electronic music studio. Interestingly enough at this time the only module that Ussachevsky bought from Moog was his envelope generator. But Ussachevsky did not want this module to work in real time with a keyboard. Instead he got Moog to redesign it so with a push of a button it could be used to add dynamic contours to taped sounds in the studio.

The argument I am building here is that the different design choices made by Moog and Buchla gave affordance to different sorts of musical usages.²⁰ Moog's design was much more attuned to conventional musical use - the sort of music which could be played on keyboards - while Buchla's designs gave affordance to the sort of experimental electronic music compositions favored by the avant garde. Moog did not know it yet, but he was on the path towards an instrument that could emulate other instruments.

I want to stress here that one should not essentialize the technology and the sort of music it could make. In terms of the sociology of technology there was "interpretative flexibility".²¹ Buchla's keyboardless synthesizers could with a degree of effort be used to make conventional melodic music and Moog's keyboard synthesizers could be used to make unconventional music. Indeed, it is worth pointing out that as well as the keyboard, Moog developed a new form of controller the "stringer" or "ribbon controller" - a taut metal resistance strip which produced a continuously varying voltage depending on where it was pressed down.

Keyboards Mean Music

But there is no doubt that over time Moog's synthesizer became a keyboard device. There were several reasons for this - primarily the answer is to be found in the "context of use". Just as Wittgenstein famously argued that the meaning of language comes

from use - so too the meaning of musical instruments is to be found in their use. Moog's explicit design philosophy was to learn from his customers and from the very start he wanted to mass produce for many different sorts of customer - not just avant garde musicians. His second ever sale was to Eric Siday, a classically-trained musician who had turned to making commercial music and in particular "sound signatures" (such as the CBS logo and a Maxwell House coffee advert). The synthesizer Moog delivered to Siday was his first ever complete system and had a fully tunable keyboard (with each separate note tunable).

It is clear that in promotional photographs of the synthesizer from around this period (see figure 4) the keyboards are clearly displayed. We asked Moog about this. He told us:²²

The keyboards were always there, and 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! This pose here [acts out the pose of the left arm extended] graphically ties in the music and the technology. So there are probably a zillion pictures like that.

The keyboard through its association with the piano carried one of the most symbolic meanings in music. It was also what many musicians were most familiar with. In order to reach more users and sell more product Moog adapted to what most users wanted - keyboards.

How Musicians Used the Synthesizer

Despite the use of keyboards, envelope shapers and waveforms conducive to imitating some acoustic instruments the early Moog synthesizers were not used much to emulate or imitate other instruments. The vast range of sounds and new sonic effects found in the Moog encouraged more the genre of exploration. Many of the early users were interested in producing sounds that had never been heard before and in general it was much easier to produce new sounds than to produce recognizable instrumental sounds. The instrument was also complex to use and rather unstable. Different modules could be patched together in a bewildering number of combinations and there were a vast number of different parameters that could be adjusted - change a knob setting by only a minute amount and you would get a totally different sound. Often analog synthesists reported getting the most fantastic sounds on their instruments which were "lost" when they returned the next day and

tried to set everything up the same way - the early instruments were notoriously unstable with oscillators going out of tune and being highly temperature sensitive. Your "best friend" in those early days was your tape recorder. If you got a sound you liked you would try and capture it on tape as soon as possible before you lost it.

Many early synthesists were rather disparaging of any attempt to imitate other instruments. Here is Jon Weiss a Moog studio musician who was trained as a violinist:²³

I had no interest in using the synthesizer to create instrumental sounds. Because 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?

Others saw the use for imitation as simply the wrong use of the instrument. For them the synthesizer is an "independent" instrument with its own sound, as David Borden, an early pioneer in electronic minimalism who used the Moog for live performance, told us, "I wanted the Moog to be Moog."²⁴

Contributing to this use of the Moog for exploring new sounds and sound washes was the whole development of psychedelic rock of which the synthesizer was an integral part. New instruments like the mellotron, unusual instruments like the sitar, and new effects like feed back, distortion, phasing and echo were all part of the psychedelic exploration. One of the first uses of the Moog was by the Doors on their Strange Days (1967) album where synthesist Paul Beaver treated Jim Morrison's voice through the Moog filter for the title track.

Despite the disdain and the practical difficulties, early synthesists found ways to emulate some of the sounds of conventional instruments. Bernie Krause and Paul Beaver were two of the best known early users of the synthesizer. They were commercial musicians who did countless studio sessions with their Moog for West Coast musicians like the Byrds and the Doors and used the Moog on dozens of Hollywood movies. They made new sounds

as well as doing imitative synthesis. Here is how Bernie Krause described their approach towards emulation:²⁵

Now, if you were to create a trumpet, what of the four available wave forms that Moog has on the synthesizer would you use?...If you could hear it in your mind and could hear what it would do, and then you had to filter it in such a way so that you got the feeling of the tone. So you wanted to be able to articulate the attack and decay of the tone, and other aspects of it, which would create that timbre.... We knew that clarinet and, for instance, some of the reed instruments were from the rectangular or square wave school, and so we'd fool with that, what does that sound like, how does tha t- if we make that right, flute sounds and things as well.

Things like flute sounds, and woodwind sounds were some of the easiest acoustic sounds to make because the standard waveforms produced had these sort of sounds. Strings were much harder because of subtleties in the white noise component which the bow produces and Beaver and Krause would struggle to produce a credible string sound.²⁶

Even artists wedded to the idea of using the synthesizer for making new sorts of sound were known to derive pleasure from successfully imitating an acoustic instrument or sound. Here is Malcolm Cecil of the early 70s cult synthesizer group Tonto's Expanding Head Band talking about how he made his first gong sound used on a track called "River Song" on their album Zero Time (1971). It was unusual for Tonto to make a sound like a conventional instrument because they rejected "imitative synthesis" and their goal was to try and capture the instrument for its own sounds. They were also purists and did not want to use conventional instruments on their all-synthesizer recording:²⁷

...we wanted this bell sound. And we figured out the envelope okay, that wasn't hard, you know, the strike and all that. But nothing sounded like a bell when we did it. So I said, "You know what, I've got this book, Helmholtz [Sensations of Tones], that I've been reading for years." I said, "I seem to remember...he analyzed the sound of the big bell in Kiev, the harmonics, and he wrote them down..." So we dialed up the harmonics from the great bell of Kiev, exactly as Helmholtz had written...fed them into the mixer, put them through the filter, put the envelope on there that we'd already figured

out, pressed the key, and out came this bell. I'm telling you, it happened! It was unbelievable! We were hugging each other, dancing around the studio. "We did it, we did it, we did it, we did it!"

Another early success was the use of the synthesizer by the Beatles on Abbey Road (1969), in particular on tracks like "Here Comes the Sun", where the increasing brightening in timbre of the Moog reflects the brightening of the sun as the song progresses. On another Abbey Road track, "Because", George Harrison uses a Moog emulation of a horn sound (made by noise added to a sawtooth waveform passed through a low-pass filter with envelope generator).

In terms of the history of the Moog the best known record is Wendy Carlos's Switched-On Bach (1968). This album went platinum and is one of the best-selling classical records of all-time. Carlos started off as a studio engineer and was very adept at overdubbing and tape splicing. She used the Moog to make Bach keyboard music but she added in many new timbres. It is Bach, but sounds very different to Bach played on conventional instruments.

The success of Switched-On Bach made Carlos and Moog famous and further reinforced the synthesizer as a keyboard instrument on which to play conventional music albeit with unconventional timbres. It also led the record industry to try all sorts of Moog gimmick albums. A whole genre of "Switched On" records appeared, such as Switched-On Baccarach, Switched-On Beatles, Switched-On Santa, etc. None of these had the artistry of Carlos and often used the Moog to play a solo line from a standard pop tune. None were hits.

The use of the synthesizer for emulation was, as I have said, rejected by many early musicians. Certainly for those who worked in the experimental tradition or who used the keyboardless Buchla synthesizer, emulation or imitation was seen as missing the point. An example here would be Mort Subotnick's use of the Buchla on his album Silver Apples of the Moon (1967) - a minor underground hit with some significant classical sales.

Many early synthesists like Carlos strove to produce sounds that were somehow familiar but which were different enough to be

interesting. Here is Edgar Froese of Tangerine Dream:²⁸

The idea is not to use this machine to duplicate a flute or a violin...What you do is use those characteristics... which will give you a flute or a violin that hasn't been heard before.

One of the characteristic sounds of the Moog is the low-pass filter which produces the fat, "squelchy" sound (it is the only module which Moog actually patented). When the filter is used with an envelope generator in the bass range, the resonant deep sound is particularly appealing and was soon discovered by synthesists.²⁹

Over the years it has become a staple of pop and rock music, as has the bass sound of the Minimoog (which uses a similar filter). Moog was himself a witness to the power of his bass sound when he was invited to bring his synthesizer to a New York studio session where Simon and Garfunkel were recording their album, Bookends (1968). Moog set up the bass sound himself for the track "Save the Life of a Child", which opens with the sound: "One sound I remember distinctly was a plucked string, like a bass sound. Then it would slide down -- it was something you could not do on an acoustic bass or an electric bass...a couple of session musicians came through. One guy was playing a bass and he stops and he listens, and listens. He turned white as a sheet."³⁰ The significance of the Moog bass sound was not lost on this session musician. The Moog not only sounded like an acoustic or electric bass, but it also sounded better. Moog liked to repeat this story, he felt that at last he was "getting somewhere". Where he was getting was that at last the Moog was finding a home amongst musicians at large, rather than being merely an instrument for the avant garde. Session musicians were some of the first to see the writing on the wall; their livelihoods were under threat. This threat was something that the powerful musicians' union (the AFM) eventually took up but they failed in their attempts to limit the spread of the synthesizer.³¹

There is no doubt that over time there was a change in the way the Moog synthesizer was used. Bernie Krause was in a position to see this change over time. At sessions he worked on, rather than explore sounds, he was asked to get particular sounds:³²

Well, can you get us the sound that you got on the Stevie Wonder album? Can you get us the sound you did on the Byrds? ...So it's usually they would dig a little bit, but not terribly deep, and so we found ourselves with this limited

repertoire of 20 or 30 sounds that we got, that were very easy to patch and do. Finally, it just got to the point where it was becoming so simple and ridiculous that we were able to replicate those sounds even on a Minimoog or a Model 10 [a smaller modular synthesizer], and we didn't even bring the big synthesizer with us because nobody wanted to explore, check out and see what could possibly happen with their music.

What was happening was that over time a series of sounds were becoming associated with the synthesizer. Furthermore the technology was itself evolving with the Minimoog hardwiring in certain sounds and making available through sound charts the reproduction of particular sounds. The use of the Minimoog for live performance further stabilized certain sorts of sounds. Sound charts enabled the users to reproduce those sounds. Well-known progressive rock keyboardists like Rick Wakeman and Keith Emerson had their own sound inscribed in such sound charts - with things like the "Lucky Man" sound to produce the familiar Minimoog yowelling sound.³³

As the technology became more miniaturized with ICs and microprocessors facilitating the use of polyphonic keyboards, the sound charts were eventually replaced on later generations of synthesizers with presets and factory sounds. By 1983, with digital synthesizers like the DX7, the making of sound was so complex that users found they could not program new sounds themselves and came to rely only on factory sounds and new sounds provided by the new cottage industry that arose in sound programming.

Sound Effects

Similar processes that I have described for musical sounds can be found in the arena of sound effects. It was, for instance, quickly apparent that the Moog synthesizer with its white noise and filter could produce "natural sounds" like wind, rain, the sound of thunder and waves. It was also easy to produce the sounds of explosions. Indeed Don Buchla used his synthesizer at a 1966 happening "Whatever it is" to stage a performance of an atomic apocalypse using his synthesizer and hundreds of photography flash bulbs going off together. Indeed the power of the synthesizer to produce weird alien-like sounds was discovered early on. Don Buchla himself used to set up his synthesizer in the open at hippy

communes. He took delight in watching stoned hippies appear from the bushes convinced that the UFOs had arrived!³⁴

The use of the Moog is sound spectaculars was pioneered by a former TV evangelist David Van Koevering. He constructed a special Moog venue, including a "Happening Stage" on a man-made island off the Coast of Florida, the "Island of Electronicus". One of his most spectacular sonic effects was staging a crash between a car and a motor bicycle:³⁵

And we'd start a motorcycle up - you'd hear a Minimoog sound like a motorcycle, you'd hear 'em kick it over, and then we'd take noise, and you'd hear 'em choke it...and by overloading the filter, causing the filter to feedback from the keyboard with the switches, you could cause that sucker to make it shift gears, and you could hear that filter screech and like a wheel would chirp...with the Doppler effect...we'd have this motorcycle flying around the room...now, we did this with two Minimoogs -- a four-cylinder sports car would start its engine...And you'd hear the motorcycle going one way and you'd hear the sports car go the other way, and a horrendous crash would happen over the stage and parts were rolling all over the room. And the audience would go nuts. They'd stand and they'd cheer and they'd clap, and it was an awesome, sonic sound effect event. A sonic picture, we'd painted a picture with synthesizers...

In the area of sound effects for radio and movies the issue of emulation is particularly interesting. It turns out that the most convincing sound effects are made "unnaturally". Here is George Martin the producer of the Beatles and who used many sounds effects with Peter Sellers on early BBC "Goon Show" records:³⁶

In fact you generally never use the real thing for a sound-effect, unless it's a frightfully good recording - and in any case people have their own ideas of what things should sound like.

One important use of the synthesizer for sound effects was its use in Star Wars (1976) where the ARP 2600 was used to make the R2D2 voices. A particularly interesting sound in that movie is the Space Bypass sound - the sound of the rocket engines of the giant space ships passing by. In this case the synthesist, Ben Burtt, found the sorts of sounds that he liked by experimenting on the ARP. However, he found the synthesized sound to be "too pure" so

he went out into the real world to record the sound which he then modified electronically:³⁷

A lot of times what I would do is find a sound on the synthesizer and say, "This is the kind of sound I'm looking for". And then I'd go out into the real world and try to find something that would match that sound. For what I'm doing, I feel the sounds the synthesizer produces are too pure.. compared to sounds generated in the real world... You can do very musical things with synthesizers, but you can't create a pickup truck crashing into a brick wall. Like for the pass-bys of the space ships I used one of my favourite sound sources, the Goodyear Blimp. It's got this low groan and two engines that beat against each other. It's a terrific sound. I slowed it down and flanged it to get the doppler effect as it went across the screen.

This is an interesting case of emulation, because physicists tell us that a space ship flying past in a vacuum produces no sound at all. So what counts as a "real" or "credible" sound here depends upon what sonic expectations are generated in listeners - a sonic expectation reinforced by the visual dimension and by the success of Star Wars.³⁸ Indeed the success of Star Wars was felt by other synthesists who now had a vocabulary to describe sounds like space ship sounds, which they could produce on demand on other synthesizers.³⁹ In this way the new sound was further reinforced and became part of our sonic culture.

Conclusion

What I hope to have begun to explore in this paper is how the process of emulation of sound in the synthesizer is one that slowly evolves in a complex socio-technical environment. The story is one of the interweaving of this technology with different "contexts of use" in the social construction of sound. Certain sounds predominate, they are recognizable sounds, sounds which are materially built into the technology and which can be reproduced. This process whereby the meaning of certain sounds stabilize can be described as a process of social construction.

It is worth pointing out that there is nothing natural or inevitable about the process of emulating sound. At stake are issues like, is the emulated sound similar or different to the original, if it is different is it similar enough to count as an emulation or is it a new sound? When it comes to the emulation of

acoustic instruments what exactly is being emulated? Is it the sound, or is it the performance of the sound on a particular occasion or is it a whole performance genre and quality of musicianship associated with the sound?⁴⁰ Sometimes it seems that the sound of a whole class of instruments is being emulated - such as "brass", or "strings". Sometimes it gets more specific and refers to a particular instrument like a snare drum or a clarinet. But then one could ask more - which particular instrument? Do all clarinets sound the same? Is it a violin sound or a stradavarius violin sound? And then who is the performer - a saxophone sound in general or a saxophone blown by Charlie Parker? And where is it being blown - in a smoky jazz club or in the Central Concert Hall Amsterdam? And lastly what about the emulation of synthesizers by other synthesizers? How is it that a machine, such as Moog, that is capable of emulating lots of other instruments can itself be emulated, as if it had only one distinctive sound? Last, but not least, does our perceptions of what counts as a "real" or "authentic" sound itself change through listening experiences? With most movies using synthesizers can listeners today tell what "real" strings sound like anyway? These issues are fascinating ones and I am aware I have barely touched upon them in the present chapter. The field of Sound Studies is still in its infancy.

Notes:

1. See, for instance, Hans-Joachim Braun, 'Technik im Spiegel der Musik des frühen 20. Jahrhunderts', Technikgeschichte, Vol. 59, No. 2 (1992), 109-131; Hans-Joachim Braun, "'I sing the body electric'. Der Einfluss von Elektroakustik und Elektronik auf das Musikschaffen im 20. Jahrhundert', Technikgeschichte, Vol. 61, No. 4 (1994), 353-373; and Hans-Joachim Braun (ed.) I Sing the Body Electric' Music and Technology in the 20th Century (Hofheim: Wolke Verlag, 2000) (and forthcoming Johns Hopkins U.P., 2002); Karin Bijsterveld, 'A Servile Imitation. Disputes about Machines in Music, 1910-1930,' in Braun I Sing the Body, pp 121-147; Antoine Hennion, 'An Intermediary Between Production and Consumption: The Producer of Popular Music', Science Technology and Human Values, Vol. 14, (1989), 400-24; James P. Kraft, 'Musicians in Hollywood: Work and Technological Change in Entertainment Industries, 1926-1940', Technology & Culture, Vol. 35, No. 2 (1994), 289-314, and James P. Kraft, Stage to Studio. Musicians and the Sound Revolution, 1890-1950 (Baltimore and London: The Johns Hopkins University Press, 1996); Trevor Pinch and Frank Trocco, 'The Social Construction of the Electronic Music Synthesizer', ICON Journal of the International Committee for the History of Technology, Vol. 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 Raghu Garud and Peter Karnoe (eds), Path Dependence and Creation, (New Jersey: LEA Press, 2001), 381-401; Trevor Pinch and Frank Trocco, Analog Days:

The Invention and Impact of the Moog Synthesizer (Cambridge, MA.: Harvard University Press, 2002); Marsha Siefert, 'Aesthetics, Technology, and the Capitalization of Culture: How the Talking Machine Became a Musical Instrument', Science in Context, Vol. 8, No. 2 (1995), 417-449; Emily Thompson, 'Machines, Music, and the Quest for Fidelity: Marketing the Edison Phonograph in America, 1877-1925', The Musical Quarterly, Vol. 79, No. 1 (1995), 131-171; Emily Thompson, 'Dead Rooms and Live Wires. Harvard, Hollywood, and the Deconstruction of Architectural Acoustics, 1900-1930', Isis, Vol. 88, (1997), 597-626; Emily Thompson, The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933 (Boston: MIT Press, 2002); Elena Ungeheuer, 'Ingenieure der Neuen Musik. Zwischen Technik und Ästhetik. Zur Geschichte der elektronischen Klangerzeugung', Kultur & Technik, Vol. 15, No. 3 (1991), 34-41; and David Morton, Off the Record: The Technology and Culture of Sound Recording in America (New Jersey: Rutgers University Press, 2000).

2. Some notable exceptions are, however, Georgina Born, Rationalizing Culture: IRCAM, Boulez, and the Institutionalization of the Musical Avant-Garde (Berkeley/Los Angeles: University of California Press, 1995); Simon Frith, Performing Rites. On the Value of Popular Music (Cambridge, Mass.: Harvard U.P., 1998); Steve Jones, Rock Formation. Music, Technology, and Mass Communication, (London and Beverley Hills: Sage, 1992); Fred K. Prieberg, Musica ex machina. Über das Verhältnis von Musik und Technik (Berlin: Verlag Ullstein, 1960); Raymond Murray Schafer, The Soundscape. Our Sonic Environment and the Tuning of the World (Rochester, Vermont: Destiny Books, 1994), originally published as The Tuning of the World (New York: Knopf, 1977); Paul Théberge, Any Sound You Can Imagine. Making Music/Consuming Technology (Hanover NH: Wesleyan University Press, 1997); Steve Waksman, Instruments of Desire: The Electric Guitar and the Shaping of Musical Experience (Cambridge: Harvard University Press, 1999); and David Sudnow, Ways of the Hand (Boston: MIT Press, 2001).

3. For overviews see, Harold Bode, 'History of Electronic Sound Modification,' Journal of the Audio Engineering Society, Vol. 32 (1984), 730-739; Joel Chadabe, Electric Sound. The Past and Promise of Electronic Music (New Jersey: Prentice Hall, 1997); Thomas Rhea, 'The Evolution of Electronic Musical Instruments in the United States', Ph D Dissertation, George Peabody College for Teachers, (1972); Curtis Roads, 'Early Electronic Music Instruments: Time Line 1899-1950', Computer Music Journal, Vol. 20, No. 3 (1996) 20-23; Bryan R. Simms, 'Electronic Music', in Music of the Twentieth Century (New York/London: MacMillan, 1986); Hans-Joachim Braun, 'Introduction: Technology and the Production and Reproduction of Music in the 20th Century', in Braun, 'I Sing the Body Electric' 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 (Methuen, N.J.: Scarecrow Press, 1995); for the theremin, see Albert Glinsky, Theremin: Ether Music and Espionage (Urbana and Chicago: University of Illinois Press, 2000).

⁴ See Theberge, Any Sound for more details.

⁵ See Waksman, Instruments of Desire 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', 198-211.

⁶ On the 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: Basic Books, 1998).

⁷ Pinch and Trocco, Analog Days.

⁸ See, Therberge, Any Sound and Pinch and Trocco, Analog Days.

⁹ See, Mark Vail (ed.) Vintage Synthesizers (San Francisco: Miller Freeman, 2nd Edition, 2000).

¹⁰ See, Pinch and Trocco, Analog Days for more details.

¹¹ See, Pinch and Trocco, Analog Days for more details.

12. The voltage controlled oscillators were built around a "relaxation" oscillator. The output shape of the waveform is a sawtooth. In addition to the oscillator circuit itself, the key elements of the voltage controlled oscillators were an "adder" for summing the input voltages into the oscillator, an "exponential converter" for converting the linear summed output into an exponential output and "wave shapers" for converting the sawtooth output into triangle, sine or pulse waveforms.

¹³ On the importance of standardization in technology in general and the social, cultural and economic assumptions built into standardization see Ken Alder, Engineering thw Revolution: Arms and Enlightenment in France, 1763-1815, (Princeton: Princeton University Press, 1997). In the adoption of the player piano developing a standard roll was crucial, see Theberge, Any Sound You Can Imagine, p. 29. For later digital instruments the development of the MIDI standard was also crucially important see *ibid.*, pp. 145-153.

14. Interview with Bob Moog, June 5, 1997.

15. Interview with Bob Moog by Joan Thomson, February 2, 1979. Yale Archive for the History of American Music.

16. Interview with Bob Moog, June 5, 1997.

17. Interview with Herb Deutsch, April 19, 1997.

¹⁸ There are other subtle differences between the Moog and Buchla synthesizers, see Pinch and Trocco, Analog Days for full details.

19. Interview with Don Buchla, April 4, 1997

²⁰ The notion of affordance is developed by Pablo Boczkowski in "Affording Flexibility: Transforming information practices in on-line newspapers" (Unpublished doctoral dissertation, Cornell University, 2001) to be revised and published by MIT Press.

²¹ For "interpretative flexibility" see Trevor Pinch and Wiebe Bijker, "The Social Construction of Facts and Artifacts," Social Studies of Science, 14, 1984, pp. 339-441. See also the essays in W. Bijker, T. Hughes and T. Pinch (eds), The Social Construction of Technological Systems (Boston: MIT Press, 1987).

²² Interview with Bob Moog, June 5, 1997.

²³ Interview with Jon Weiss, May 8, 1996.

²⁴ Interview with David Borden, May 3, 1966.

²⁵ Interview with Bernie Krause, August 24, 1998.

²⁶ Indeed throughout the 1970s the quality of a synthesizer's string sound would be the benchmark for its emulation capabilities.

²⁷ Interview with Malcolm Cecil, March 31, 2000.

²⁸ Interview with Edgar Froese in Darter and Armbruster (eds), Art of Electronic Music, p.173.

29. A good example is the Tonto track "Cybernaut" on Zero Time (1971).

30. Interview with Bob Moog, June 5, 1996.

³¹ For more details see Pinch and Trocco, Analog Days.

³² Interview with Bernie Krause, August 24, 1998.

³³ The Emerson, Lake and Palmer, hit single "Lucky Man" (1970) with its Moog solo at the end is one of the best-known uses of Moog in rock during this period.

³⁴ See Pinch and Trocco, Analog Days, for more details.

³⁵ Interview with David Van Koevering, January 30, 1999.

³⁶ George Martin, All You Need is Ears- (London: Pondview,1979) p. 94.

³⁷ Interview with Ben Burtt, in Darter and Armbruster, Art of Electronic Music, p.241.

³⁸ Also part of its credibility rests on other renditions of spaceship sounds in earlier movies and Science Fiction TV shows.

³⁹ For more details see Pinch and Trocco, Analog Days (2002).

⁴⁰ Some of these issues are further explored in Trevor Pinch and Karin Bijsterveld, "'Should one applaud?' Breaches and Boundaries in the Reception of New Technology in Music," submitted to Technology and Culture.