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Technology and institutions: living in a material world

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Abstract This article addresses the relationship between technology and institutions and asks whether technology itself is an institution. The argument is that social theorists need to attend better to materiality: the world of things and objects of which technical things form an important class. It criticizes the new institutionalism in sociology for its failure to sufficiently open up the black box of technology. Recent work in science and technology studies (S&TS) and in particular the sociology of technology is reviewed as another route into dealing with technology and materiality. The recent ideas in sociology of technology are exemplified with the author's study of the development of the electronic music synthesizer.

Introduction

What is the relationship between technology and institutions? Is technology itself an institution? How in general are sociologists to cope with materiality; the world of things and objects of which technical things form an important class? And how well does the new institutionalism in sociology deal with technology and materiality?

Most sociologists take it as their prerogative to examine the social dimensions of phenomena. For example, Neil Fligstein, in a recent attempt to revive neoinstitutional sociology in the explanation of organizations and organizational change defines his task as explaining how "social institutions, defined as rules that produce social interaction, come into existence, remain stable and are transformed" (Fligstein 2001:106). The traditional sociological approach carves up the world in this way such that sociologists deal only with social things. The world of objects, machines, and materials are left unanalyzed or considered the territory of others, perhaps scientists and engineers.

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It is a commonplace within modern sociological theory to talk about the duality of structure and agency (Giddens 1984; Bourdieu 1999; Sewell 1992). Sociologists also point to the need to treat symbolic constructions and "material practices" as mutually constitutive (Friedland and Alford 1991; Mohr and Duquenne 1997). This article has no quarrel with the mutual constitution of structure and agency or culture and practices. Rather I want to examine what is exactly meant by the "material" of material practices. And when modern social theorists touch upon material constraints such as time, space, and material resources (e.g., Giddens 1984), do they offer a thorough going analysis of materiality that shows the material world is, in the language of structuration theory, both enabling and constraining?

As a starting point consider the position of John Searle who has recently treated the world of social construction and institutions within his general philosophical theory of biological naturalism. Searle draws a clear analytical distinction between physical forces and social forces (Searle 1995 and Searle 2006). Searle uses a parable of a village erecting a wall against outsiders that is then replaced with a symbolic wall, to show how physical force and processes of signification can serve the same purpose in social life. Searle, however, neglects the possibility that the physical and social might act together. Another example illustrates how this might happen. Simple physical devices, speed bumps (known in Britain as a "sleeping policeman"), are used for traffic calming. In this case physical force directly enforces a moral order previously founded upon signification processes such as traffic signs (Latour 1994). For Searle, signification processes are at the heart of social construction. But machines and the physical and material world can also be interwoven into signification. Social construction must include both.

Of course, sociologists encounter material objects all the while—the discipline would scarcely be possible if it did not, but such objects are often treated more in terms of the social or cultural significance they produce or the affect of such objects upon social relations rather than in terms of how the social is integral to the constitution of such objects. Typical sociological framings are: What does this car mean or signify for consumption? How has the telephone changed society? How does computing and the internet increase or decrease the "digital divide"? How do off-shore call centers affect global patterns of migration amongst knowledge workers?[1] Such approaches leave the material realm, the motorcar, the telephone the computer, and the Internet, unexamined. They fail, in the parlance, to "open the black box" of technology. The material realm provides an object for signification processes to glob onto, but these processes are independent of the actual working or material composition of the object.

The distinction between a pure social domain, a world where only human capacities and affordances are granted, and the rest of the world—a non-human

[1] See for example DiMaggio and Hargittai (2001) on the digital divide where the actual technology of computing remains unexamined. Another telling example is Yakubovich et al. (2004), who although examining a heavily technologically mediated realm—the electrical system—define social construction to be process that has nothing to do with the technology. On the telephone, Claude Fischer's (1992) influential book on the social history of the telephone leaves unexamined the actual technology of telephones.

domain—makes little sense. The human and non-human are always mixed up together and it is this fundamental duality that needs to be attended to. It is immediately obvious that we humans are made of material stuff (mainly water I believe) and as soon as we inquire into how we do things unique to humans like represent and intervene, and produce and interpret—in short the domain of language—we quickly enter into discussions of our biological and brain functioning. And biology if it is anything deals with the material domain of cells, neurons, genes, proteins, and so on. It is also rare these days for humans to encounter an un-mediated non-human world—"nature in the raw" as it were. As social geographers have pointed out, landscapes have been shaped for centuries by human intervention. Even in the natural sciences scientists rarely encounter "natural" objects directly; the entities they deal with are often highly prepared and mediated—whether genetically purified mice (Rader 2004) or high energy particles (Knorr-Cetina 1999).

Sociologists of course recognize that society and social institutions have important material elements. Marx famously grounded his sociology in an analysis of factories, technology and how the material world constrains society. But the Marxist analysis neglects the enabling aspects of materiality and technology (MacKenzie 1984). Bourdieu (1977) considers the materiality of space and in particular buildings, as Gieryn has pointed out as, "merely as external and autonomous forces structuring social practices with no necessary involvement of knowledgeable agents" (Gieryn 2002:37). Goffman (1959, 1961), also pays attention to the material arrangements of people and objects within the "interaction situation." Notions like "co-presence," "face work," and "front and back stage" draw attention to the material arrangements among human beings that enable and constrain social interaction, but Goffman treats materiality per se as something like a stage on which all the interesting performances occur. Giddens (1984) has pointed to the importance of space and time in sociology. Commenting on the influence of Goffman and Garfinkel, Giddens writes that, "The substantially 'given' character of the physical *milieux* of day-to-day life interlaces with routine and is deeply influenced in the contours of institutional reproduction" (Giddens 1994:xxv). Giddens does bring space and time into sociology, but like Goffman, he talks about the use of space as providing settings for interaction. As Gieryn (2002) and others (Hannah and Strohmeyer 1991; Sorper 1985; Soja 1989) have pointed out Giddens ultimately treats materiality as something which humans deal with through their own interpretative frames and agency.

The recent focus on "material practices" by some sociologists moves us in a promising direction. Mohr and Duquenne (1997) and Friedland and Alford (1991) rightly point to the need to overcome dualisms between culture and practice or idealism and materialism. Mohr and Duquenne (1997) in their exemplary study of poverty relief in New York City at the turn of the twentieth century characterize much of the theoretical work in sociology of the last twenty years as having been dedicated to overcoming an opposition between "materialists" and "idealists" and call for the mutual structuration of symbolic practices and material practices. But what exactly do they mean by the "material" in "material practices"? They describe the material world as "the world of action" or "the structure of demands of the everyday world" (Mohr and Duquenne 1997:309). What they mean by material practices is something akin to the ordinary human practices of everyday life. In effect, material practices are equivalent to social practices. They give examples from Clifford Geertz's research on sheep raids or cock fights and from Friedland and Alfred's research of buying and selling commodities. The material practices uncovered in Mohr and Duquenne's own research entail things like "giving money, food and shelter." The word "material" here seems to signify a practice that is grounded in the everyday, in the world of material things and may involve the exchange or manipulation of material things but by and large the materialness of the things does not itself figure in the analysis. What is important for these analysts are the social practices which so happen to involve material entities. For instance, Mohr and Duquenne draw attention to the practice of giving shelter and the "institutional logic" involved. They note in passing how changes in organizational form such as the replacing of "poor houses" and "alms houses" with settlement houses, half-way houses and the like transformed the habits and living conditions of the poor, but the systematic treatment of materiality and transformations in the technology of building and sanitation does not figure in their analysis.

Other social sciences have also started to come to terms with materiality. Feminists, queer studies, and indeed cultural studies deal routinely with the body and this means materiality. Anthropologists such as Geertz (1973), Douglas (1986), and Stathern (1992) address the issue of material culture. Philosophers have also given us clues as to how to avoid the dualism. Wittgenstein (1973) at the beginning of *The Philosophical Investigations* shows how the origins of language games are found within human activities in a material world—like building a house. In cognitive science Hutchins (1995) has developed the felicitous notion of "distributed cognition" to capture how cognitive capacities are distributed between assemblages of humans and machines which work together to achieve particular tasks such as landing an airplane or navigating a ship. In the field of human computer interaction Suchman's (1987) ethnomethodologically inspired studies of how people interact with machines have usefully introduced the notion of "situated action" to capture how humans act in concert with machines. One of the few groups of sociologists to explore materiality have been those interested in space (Gieryn 2002; Mukerji 2002; Carroll-Burke 2002) and this group, significantly for the argument that follows, draw upon the new sociology of technology.

This article also attempts to bring the material realm into sociology via the sociology of technology. I examine in more detail what neoinstutionalists in the study of organizations have to say about technology and materiality. I look at how they talk about skill. I then introduce work in the recent sociology of science and technology. The main empirical body of the paper offers several vignettes from my own recently completed study of the development of the electronic music synthesizer (Pinch and Trocco 2002). I try and show the salience of ideas in the sociology of technology and offer some new categories for thinking about agency and identity in dealing with technology. I conclude by calling for more integration of the neoinstitutional approach within sociology with the sociology of technology[2]—the benefit will be a much more robust understanding of institutions and institutional change.

[2] Thomas Gieryn and his student Nicholas Rowland (e.g., Rowland and Gieryn 2008) are engaged in a similar project.

The new institutionalism

The "New Institutionalism" that has come to dominate much organizational sociology in the USA in the last decades (Mizruchi and Fein 1999: 678) explicitly drew a line under its structural functionalist predecessors. Nailing itself to the mast of the interpretive tradition, whether Berger and Luckmann's (1984) treatise in the sociology of knowledge, or Giddens (1984) theory of structuration or Bourdieu's (1977) theory of practice, the aim was to recast the way that we understand organizations. The power of the new approach was to challenge the notion that resources are real and distributed around organizational fields as given determinants of outcomes. By calling attentions to rules, cognitive categories and legitimacy, the new institutionalism was able to show the importance of ideas for organizations. The interpretative tradition in sociology was lauded (March and Olsen 1984; Scott 1995; DiMaggio and Powell 1991) as a way to bring culture, and meaning back into the institutional analysis of organizations (Friedland and Alford 1991) and thereby challenge functionalist explanations such as efficiency. Like all radical movements, the new approach had its manifesto—the so-called bible of new institutionalism, Powell and Dimaggio's (1991) edited collection, *The New Institutionalism in Organizational Theory.*

Given the positivistic reflexes of many North American sociologists it can be questioned how deep the changes argued for by phenomenologically inspired work were (e.g., Leuenberger and Pinch 2000). There are, however, some encouraging signs. Fligstein's (2001) recent call for a neoinstutionalist focus on fields and micro domains is important and meshes well with other approaches in microsociology. Fligstein draws upon symbolic interactionism to posits a new social theory of agency, whereby agency is conceived as a social skill. Fligstein defines social skill as the "ability to engage others in social interaction" (Fligstein 2001: 105–106). This introduction of skill is welcome but does not go far enough.

There is another literature on the sociology of skill that Fligstein does not mention. Scholars in the sociology of science and technology and the sociology of work are familiar with this notion of skill.[3] For them skill is something that social actors, including scientific and technical workers, possess and that is crucial to their jobs. In this case the skill is more akin to a bodily or physical skill—it is the ability to get a job or task done. Craft unions are built around skilled workers. Without skills many technical tasks cannot be accomplished (Ravetz 1971; Collins 1974, 2001; Harper 1987; Barley and Orr 1997; Orr 1996). The deskilling debate initiated by Braverman (1975) was about whether and to what extent workers are losing such skills in late-stage capitalism.

For the sociology of science and technology skill is a key concept. Collins (1985), for example, argues that debates over whether or not experiments have been replicated can be understood as arguments about who has or has not the appropriate skill to operate complicated pieces of equipment that must coax a newly claimed

[3] Another approach to skill is offered by Garfinkel (1967) and his studies in ethnomethodology. The ethnomethodological version of skill is "competence". But for Garfinkel like Fligstein, embodied skills are only rarely the focus of analysis.

phenomenon from the noise. Collins's argument builds upon the earlier work of Kuhn (1962) who shows that scientists spend much of their training acquiring the skills to produce experimental phenomena within a given tradition of work or paradigm. Most scientific training is not about testing nature but about testing the scientist to see if they have the requisite skills to produce the correct answers. Ethnographies of skill (Collins 2001; Orr 1996; Pinch, Collins, and Carbone 1996; Lave and Wenger 1991; Harper 1987) show the extent to which many skills depend upon tacit knowledge. Tacit knowledge is knowledge that can be acquired and passed on, but that cannot be articulated. The skill involved in learning to ride a bike is a good example of tacit knowledge (Polanyi 1958). At one moment, kids do not possess the skill to ride a bike, but at a later moment they have acquired the skill. They have clearly learnt something but it is not clear what specific knowledge has been acquired (we do, however, know something about what *has not* been passed on—for instance neither explicit knowledge of the laws of physics nor of the laws of balance seem necessary). Tacit skills are typically not learnt from books and written manuals; such skills are learnt in practice "by doing," on the job. Pottery, woodwork, and cooking are full of such skills, as is car maintenance and much of science, technology, and medicine. Further elements of skills have been identified and the discussion has moved on to how and under what circumstances different components of skills can be explicated (Pinch et al. 1996).

Institutions obviously depend upon these sorts of skills as well as social skills. An organization like a hospital can only function because the doctors and nurses possess the bodily skills to carry out surgical operations, make other medical interventions, and care for patients. If social skill in Fligstein's sense was all there was an organization would quickly collapse. Being able "to engage others in social interaction" is not going to be enough if you are a surgeon facing a critically ill patient. On the other hand, Fligstein is perfectly correct in one respect; without social skills—being able to talk, read gestures, and so on—the hospital as an organization would collapse. Both senses of skill are needed for a complete analysis.

The significance of this sociological literature on skill in the sociology of science and the sociology of work for the neoinstitutional project is far from trivial. Institutions have an inescapable material dimension and part of the agency that actors bring to institutions is their work in producing and reproducing (and sometimes changing) the material dimensions of institutions. Likewise materiality itself exercises a form of agency and part of the agency that materiality brings to institutions is the work of producing and reproducing (and sometimes changing) the social dimensions of institutions. Indeed, we neglect the material aspect of institutions at our peril, especially if we want to understand institutional change. Institutional changes are often accompanied by rapid changes in technology—and technology is an important component of materiality.

The new institutionalism in sociology has surprisingly little to say about the topic of technology. Walter Powell and Paul Dimaggio's 1991 edited collection, *The New Institutionalism in Organizational Theory*, despite paying lip service to the need to address the material and symbolic aspects of institutions and the occasional references en passant to technology, fails to analyze technology except in that it provides a background technical environment where organizations exist. Typical is the piece by Meyer and Rown where technology is a source of "myth binding on organizations" (Meyer and Rown, p. 45 in Powell and Dimagggio 1991).[4] One of the few exceptions in the volume that gives more attention to technology provides a nice way into thinking about this topic in relation to institutions. Ronald Jepperson gives the example of a microcomputer's basic operating system (DOS) that he says "appears to be a social institution relative to its word-processing program (especially to a software engineer)" (Jepperson in Powell and Dimaggio 1991: 146). This example caught my eye because it is one of the few instances where a piece of technology is explicitly described as an institution.[5]

For Jepperson and the other sociologists writing in that book, institutions are taken to be sets of rules or patterns whereby social actions ands practices are ordered. To be institutionalized, actions and practices must be reproducible. For Jepperson, DOS provides a highly constraining set of rules—the way the software interacts with the hardware of the computer is prescribed and proscribed by DOS while a word processing program allows the user to write in many different ways. DOS is actually a nice example of a technological institution because today the possibility to run programs in DOS has all but vanished for most users. Nevertheless we are still constrained by this operating system that is now embedded within other programs like Windows. Because DOS has becomes less visible the institution is actually more powerful. The embedding or freezing of choices within scientific and technical systems, what the French philosopher Gaston Bachelard calls *phenomenotechnique*,[6] makes technology actually one of the most powerful institutions in Jepperson's sense we as social scientists face. It is because social choices appear to have vanished from technologies, or are so deeply embedded within technical structures that they become invisible to all but the technical experts, that technologies are powerful institutions.

What is technology?

But what exactly is meant by technology? The word is elusive and immediately problematic. Its origins can be traced back to the Greeks, with the word *techne* meaning art or craft and comprising activity within the mechanical arts.[7] Today we usually think of technology as being about artifacts, processes, and machines, and the knowledge—often based in engineering—used to design and operate them. For much of the media technology has taken on an even more limited meaning: it stands for particular devices of the age of information technology like computers, internet, mobile phones, and so on. Leo Marx (1994) has pointed out that the word tech-

[4] The reason for this is they believe that for many organizations like universities and museums, the *cultural* pursuit of legitimacy is a more profound cause of isomorphism.

[5] In the study of productive organizations such as auto plants the neoinstitutionalists are more likely to recognize the role of technology as a factor in bringing about convergence, but again technology as an object is left "black boxed."

[6] This term is used in this way by Bruno Latour and Steve Woolgar (1979) in *Laboratory Life*,

[7] This instrumental meaning has come to dominate but we should not forget also the meaning of *techne* within the fine arts and arts of the mind as poiesis—a "bringing forth" or "revealing" to which Heidegger (1977) draws attention.

nology did not come into general usage until the late nineteenth century. Marx interestingly notes that technology in that period actually had a much broader usage than the narrower meaning of today. Technology was associated with the big new technological systems that were sweeping America: railroads and telegraphy, and later the telephone and electricity. These technological systems, as the historian of technology Hughes (1984) has powerfully shown for the case of Edison and the electric power utilities he founded, were combinations of the technical, political, social, and economic. New breeds of system manager arose, developing the new managerial skills and new forms of accountancy needed to operate these systems.[8]

It is obvious that technology, however it is defined, should be of concern to sociologists. The changes associated with the rise of the steam engine, the spinning jenny, interchangeable parts, canals, trains, the automobile, mechanized warfare, radio, TV, nuclear weapons, genetics, agribusiness, biotechnology, the Internet, and nanotechnology to name but a few, have transformed and are currently transforming human experience, life and death, and social institutions. Technology is something nobody can afford to ignore. Economists like Schumpeter, Paul David, and Chris Freeman look to understanding technological change as the means to understand economic change. Karl Marx's theory of political economy was famously founded upon an analysis of the power of machines and the process of technological change during the industrial revolution. Social critics like Lewis Mumford have long questioned the impact of technology on our cities. Philosophers as diverse as Martin Heidegger, Jacques Ellul, Herbert Marcuse, Langdon Winner, Don Idhe, and Andrew Feenberg have reflected upon how human beings are enframed by technologies.

The sociology of technology

Within sociology the systematic analysis of technology has, however, been slow to develop. The field of sociology of technology as a sub-field of sociology is still in its infancy. There was an important earlier tradition of work associated with Ogburn (1950) and the notion of "cultural lag"—the idea that societies may adopt a technology like guns relatively quickly, but take longer to change cultural attitudes such as using guns as weapons to kill people in wars. Robert Merton also was someone who was interested in technology—famously in his Ph.D. dissertation (Merton 1970) on the origins of the scientific revolution, where he pointed to the role of technology as one of the co-factors in the emergences of the scientific revolution in a particular time and place.[9] There are also important social theorists who claim that certain features of technology or types of technology demand new sorts of social arrangements, whether Ulrich Beck's risk society (Beck 1992), or Manuel Castells's network society (Castells 1996). But what is missing from this

[8] Sociologists of technology have typically differentiated between "material technologies" that are predominately peopled by material artifacts and "social technologies" where the onus is put upon routines and practices followed by humans (Pinch et al. 1992). For example, the classic Weberian bureaucracy is a social technology whereas the space shuttle is a material technology.

[9] The effect of Puritanism on the rise of science is part of this and has become known as the "Merton Thesis"—see Shapin (1988).

work is an analysis of how an understanding of technology and indeed the material world in general could be an integral part of the building blocks of sociology.

In the 1980s, a new sociology of technology emerged heavily influenced by phenomenology and in particular by the sociology of scientific knowledge (Pinch and Bijker 1984; MacKenzie and Wajcman 1985; Woolgar 1985; Latour 1987; Bijker et al. 1987). The crucial move in the new sociology of technology has been the attempt to uncover and analyze the choices embedded within technologies and technological regimes and show how these choices are tied to wider societal concerns. One obvious means to do this and "open the black box of technology" is through the use of history. Historical analysis shows that things have not always been as they are today and thus exposes the potential for showing how things could be and were different. In terms of the analysis of institutions, Foucault's work is particularly instructive here. His focus was mainly on what he called "technologies of the self" but his examination of specific disciplining institutions like prisons drew attention to their material dimensions. The panoptican is well-known but the separate system of prison care initiated by reformers like Jeremy Bentham (Ignatieff 1978) included many new technical devices such as the architecture of rooms to avoid prisoners seeing each other; new forms of individualized tread mills; and new kinds of signaling devices for corralling prisoners. Foucault's broad-brush technique did not examine these technical artefacts in detail—but it nicely shows that, what Goffman calls, "total institutions" like prisons, hospitals, and asylums are dependent upon material arrangements and technical devices.

It is the investigation of particular technical devices that is so crucial, yet at the same time hard to do because such devices often fall within the purview of engineering and design. In short, for the sociologist to fully engage with the working of a technology often means that the sociologist must acquire a great deal of engineering knowledge and learn about engineering practice. Having opened the black box, the sociologist must then endeavor to show how societal interests have shaped the very design of a technology. Influenced like so many of us, by Berger and Luckmann (1984), the challenge becomes to understand how technical objects themselves are socially constructed. This approach does not deny that technologies are real or that they have massive effects on social interaction as Giddens and others have argued. But to understand how technologies enable and constrain social interaction, it is important not to take either their constraining or enabling features for granted and study both how technologies could be different and how social interaction built around technologies could be different.

SCOT

The social construction of technology (SCOT) approach[10] has been developed by an amalgam of sociologists, historians, and Science and Technology Studies scholars over the last 20 years (Pinch and Bijker 1984; Bijker et al. 1987; Bijker and Law 1992; Bijker 1995a, b; Pinch 1996). Studies have been carried out of technologies as

[10] The closely aligned "social shaping" approach has also been important, see MacKenzie and Wajcman (1985). Also feminist work on technology has been influential—for a review, see Wajcman (1991).

diverse as bicycles, plastics, electric lighting (Bijker 1995a), missiles (MacKenzie 1990), cars (Kline and Pinch 1996) and digital newspapers (Boczkowski 2004). To illustrate some of the key ideas I draw on my own study of a piece of technology, the electronic music synthesizer (Pinch and Trocco 2002).

The synthesizer study

Something remarkable happened between 1960 and today. The world back in 1960 was a lot quieter. A few people might have heard the experimental music of composers Karl Heinz Stockhausen and John Cage or have been exposed to the shriek of one of the first electronic instruments, the Theremin,[11] in Hollywood movies such as *Spell Bound*. Today, however, we are saturated with electronic sound. Car alarms beep, mobile phones chirp, and an electronic cacophony accompanies every contestant on television who becomes a millionaire. The origins of this electronic soundscape can be traced to one engineer, Robert Moog (known affectionately by everyone in the field as Bob Moog) and his invention of the synthesizer.[12]

Here is how, Bob Moog, describes the moment in the basement of an isolated upstate New York town, Trumansburg, when he and avant garde composer Herb Deutsch made their first synthesizer module:

> 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? ((Pinch and Trocco 2002: 26)

This "weird shit" has transformed the world of sound over the subsequent forty years. Much of the technology for making new electronic sounds is descended from this first commercial device for making electronic music, the Moog synthesizer (Théberge 1997; Chadabe 1997).[13]

The Moog synthesizer is literally a black box (or to be more accurate several black boxes) for making sound. The newly discovered transistor enabled Moog to make his device much smaller than the room-sized tube machines controlled by

[11] The Theremin invented by Russian physicist Leon Theremin is unique because its high pitched oscillator is controlled by the operator moving their hands near two antennas—there is no physical contact with the instrument at all. It can be heard to good effect on the record "Good Vibrations" by the Beachboys.

[12] Moog died in August 2005. His influence is increasingly recognized with him winning the Polar Prize for music in 2001 and a Technical Grammy in 2002. A documentary, "Moog," about his life has recently been released.

[13] Sound itself is a key part of the new institution of electronic music. In sociology, we are familiar with visual materials but we have thus far paid little attention to sound. Sound is part of the material world. Not only must we understand how new sound technologies come into being, and are used but we must also try and understand the new sonic experiences, which these technologies enabled. The study of sound, music, noise, and even silence is part of the new interdisciplinary area of "sound studies"—see for instance, Thompson (2002), Sterne (2003), Bijsterveld and Pinch (2004).

punched tape, which preceded it. The technology was analog—it worked with continuously varying voltages. It contained sources of sounds (oscillators and noise sources), ways of processing sound (filters, envelope shapers and amplifiers) and ways of controlling sound—Moog's main controller was an organ keyboard. All the different modules could be connected up in flexible ways by wires (known as patch cords—rather like an old analog telephone exchange). Different musical parameters varied according to the different "control voltages" fed into them. For instance, the pitch of an oscillator increased with increased voltage. Outputs could be connected to inputs facilitating all sorts of musical effects such as vibrato and tremolo and all sorts of different sounds could be made by connecting up the modules in complex ways.

Moog developed this technology from a hobbyist background (his father, an engineer for Con Edison in New York, was one of the first amateur radio operators in America, and built a huge basement workshop in which young Bob tinkered). He first made hobbyist instruments such as the Theremin. Crucial for Bob's development of the synthesizer was a chance encounter in the early 1960s with New York avant garde composer, Herb Deutsh, who teamed up with Bob and told him what sorts of sounds and controllers he would find musically useful. From this collaboration stemmed the synthesizer. Moog had his first synthesizer factory in Trumansburg, 12 miles north of Ithaca where Cornell is located and where Bob was a graduate student in engineering physics.

Interpretative flexibility

One of the central ideas in the social construction of technology is that the meaning of a piece of technology is acquired within social groups. Technologies, rather than developing under there own immanent technical logic (referred to by Winner (1977) as "autonomous technology") acquire meanings in the social world and these meaning shape and constrain their development. Often in the initial stages different meanings of a technology will coexist, some in contestation with one another. For example, the IBM PC has a very different meaning from that of the Apple Macintosh. This difference in meanings is known as "interpretative flexibility" (Pinch and Bijker 1984). The term interpretative flexibility comes originally from the sociology of scientific knowledge where it is used to denote the competing interpretations of experiments found at the research frontiers during scientific controversies (Collins 1985). A good example of interpretative flexibility in the history of the synthesizer is a rival technology to that of Moog's, developed in 1964 by engineer and artist Don Buchla.

While Moog was a classic 1950s engineer (complete with pen protector) working in rural Trumansburg who had occasional contacts with the avant garde in New York City, Buchla was the engineer for the hippies. He made synthesizer modules for Ken Kesey's merry pranksters to use at "acid tests" (Pinch and Trocco 2002). Kesey's famous bus "FURTHER" was equipped with Buchla modules and Buchla also made equipment for the Grateful Dead (with whom he was friends). Buchla worked at the San Francisco Tape Center and was part of the burgeoning Haight Ashbury experimental music scene that included composers like, Terry Riley, Steve Reich, and Pauline Oliveros. Buchla's synthesizer, known as the Buchla Box, shared with Moog the technology of transistors, voltage control, and modular construction, but there was "interpretative flexibility." Buchla sought a new meaning in the synthesizer. For him, the new source of sound was not to be controlled by anything so prosaic as a keyboard; instead he developed new sorts of controllers (e.g., arrays of pressure-sensitive touch pads), which were not limited to music made from the chromatic twelve-note scale of the conventional keyboard. Buchla wanted to use the synthesizer to make a new sort of music.

At the core of the burgeoning electronic music movement in the 1960s were thus two rival machines and two rival visions of the future. Moog wanted to make reliable machines that could be used by all sorts of musicians, including commercial musicians. Buchla wanted electronic music to be a tool for experimentation to be used by the avant garde. Buchla refused to call his synthesizers machines; he referred to them as instruments, with each "Buchla Box" exhibiting unique characteristics.[14] Buchla had his own names for modules that reflected his artistic vision. For example, he called his white noise source (useful for making sounds of wind and waves), the "Source of Uncertainty."[15]

Standards

Moog built his synthesizer around what became known as the volt-per-octave standard. This means that changes in a control voltage of one volt for the different modules corresponds to a pitch change of an octave. Much work in the history and sociology of technology has shown the importance of standardization (Alder 1997; Schaffer 1992; O'Connell 1993; Star and Bowker 1999). Standards are rarely simply technical matters; they are powerful ways of bringing a resolution to debates that might encompass different social meanings of a technology. Standards are set to be followed; they entail routinized social actions and are in effect a form of institutionalization. In the case of Moog's volt-per-octave standard he was standardizing around a particular meaning of the new instrument—that it was to be used for playing music where intervals and octaves meant something. Buchla, with his radically different vision of music and his rejection of standard keyboards, had oscillators that were non-linear and had no correspondence to a volts-per-octave measure at all. When other synthesizer manufacturers like ARP of Boston and EMS of London entered the market later in the 1970s, it is notable that they all adopted a form of the volt-per-octave standard. Later, in the digital age of the 1980s, standardization became even more important and different American and Japanese synthesizer manufacturers organized a special conference to develop

[14] Buchla and Moog for a while resisted using the name "synthesizer" for their invention. Moog wanted to differentiate his "real time" machine from the paper tape controlled room-sized computer known as the RCA Mark II Synthesizer used at the Columbia-Princeton Electronic Music Center. Buchla disliked the connotation of synthetic as in a copy of the real thing.

[15] Buchla was very influenced by the randomness aesthetic of John Cage who was a visitor to the Tape Center where Buchla worked.

a new digital standard, MIDI (Music Instrument Digital Interface), that allowed different makes of synthesizers to be hooked up together and more crucially with personal computers.

Technological frames

Technologies and the social groups within which technologies take on meaning are tied together within what can be called a "technological frame" (Bijker 1995a). Rather like Kuhn's notion of a paradigm in science, this provides a conceptual framework as well as a mode of practice and exemplar for the new technology. Eventually a frame may get downshifted into the machine itself and so constrain subsequent meanings and usages. For example, the Microsoft technological frame has become over time the Windows frame. It is clear that from the start Moog and Buchla operated within different technological frames. Moog as a fifties engineer working in upstate Trumansburg adopted conservative fifties engineering values. He wanted to make a reliable piece of technology that could be widely used and sold to a number of different groups of users. Buchla, on the other hand, saw himself more as an avant garde artist, who made instruments for his like-minded friends and fellow composers. This difference is captured in the different ambiences of their respective factories. Moog's factory employed local woman whose quilting skills could be adapted to the task of soldering delicate electronic components to circuit boards. One senses it was a very ordinary American small business—an assembly line in a rural town, with local workers and "easy listening" tuned in on the radio. The shop environment was working-class and matter-of-fact. Buchla's off-beat shop—from the lighting, to the piped-in politics, to the ambient counter-cultural atmosphere—was more like an on-the-job "happening." Buchla employed fellow artists, philosophers, and Zen Buddhists who worked in total silence.

Closure

The social construction of technology approach traces different meanings of a technology over time. The concern is with how new meanings arise, old meanings vanish, and how choices get frozen. Interpretative flexibility often vanishes and the job of the sociologist becomes to explain how one particular meaning comes to predominate; how "closure" is brought about (Pinch and Bijker 1984). Closure is another term introduced from the sociology of scientific knowledge where it is used to explain how a consensus over experimental facts develops amongst the relevant community. The process of analyzing closure for a technology resonates with neoinstutionalist Walter Powell's claim that, "The critical agenda for institutional analysis should be to show how choices made at one point in time create institutions that generate recognizable patterns of constraints and opportunities at a later point." (Powell in Powell and Dimaggio 1991: 188).

In terms of Moog versus Buchla, what happens over a period of time is that Moog's vision for the future comes to pass. The choices he made turn out to be the winning ones. One reason for this is because Moog stays with the standard keyboard.[16] And here the symbolic and rhetorical meanings of technologies become important (Bazerman 1999). Increasingly pictures of Moog's instruments began to appear in sales brochures, advertising material, and in the media with the keyboard prominently displayed. We asked Moog the reason for this:

> 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. (Pinch and Trocco 2002:60–61)

Most musicians had some familiarity with keyboards and thus they quickly adapted to the new instrument. Buchla's control systems were complex and needed the operator to invest far more time in learning the instrument.

Users

The other important issue in terms of Moog's success concerns his relationship with users. In the sociology of technology, the importance of users has been gaining increasing attention (Mackay and Gareth 1992; Kline and Pinch 1996; Oudshoorn and Pinch 2003). Users of technology have to be "configured" as Woolgar (1991) has put it or "scripted" as Akrich (1992) suggests. A technology may succeed or fail depending on how well users are able to operate it. Institutional analysis is particularly instructive on this point. Highly institutionalized processes are ones where humans repeatedly act in the same way, and that is exactly what technologies do to their users. It does not mean that uses are determined or that users cannot come up with new meanings and uses. History of technology teaches us that indeed they do. For instance, Kline and Pinch (1996), in their study of the use of the early Model T on farms in the USA show how farmers converted their Model Ts into stationary sources of power for washing machines, farm implements, and the like. Although new uses of technologies are, as Von Hippel (1988) notes, a source of innovations, it is the repeated way we coordinate our actions with machines that forms part of the choreography of modern social life. Just look at cell phone users for confirmation of this point. We learn new gestures and our bodies experience new injuries as a result of the new disciplining that technologies bring their users.

The place of users in Moog's technological frame was particularly important. He strived to understand what his users (his customers) wanted and he devised new ways to learn from them such that he could, in turn, discipline them more effectively. He opened up his factory and held a summer electronic music workshop there where young composers could have access to his new technology and he could study how they used it. This eventually turned into his factory studio that he encouraged local musicians to use for free at night. During the day he offered free tuition to his customers, facilitating further interaction with his users. The studio became a kind of test laboratory for "idiot-proofing" the machine. Most musicians had no experience with electronic equipment and were notorious for sticking wires in where they were

[16] The keyboard although it looks like an organ or piano keyboard is actually monophonic (plays one note at a time); polyphony and touch sensitivity were only introduced later.

not supposed to go. Moog constantly tweaked his synthesizer according to what his users wanted. He added touch sensitivity to his keyboard; he made his oscillators more stable; and he added many more technical changes. His second ever customer, Eric Siday, wanted to use his new Moog not to make music but to make the few seconds of sound (known as a "sound signature") that sell a commercial product on radio or television. Siday had Moog build him a special keyboard with each note being tunable. It was Siday who developed this lucrative new industry in New York, making the "burp" of a Maxwell House coffee percolator in a well-known ad. By appealing to wider groups of users, Moog made his synthesizer more and more useful to different sorts of musicians. Buchla, on the other hand, with his singular vision of electronic music as experimental music found his instruments limited to academic composers and the avant garde.[17] Moog learnt from his users whilst Buchla's vision told him what users wanted.

Wider culture

In studying the role of users the sociologist of technology must deal with the wider world of social meanings, hierarchies of power, and flows of resources within which users operate. Organizations are of course embedded in wider constellations and structures of meanings. The synthesizer was born in the 1960s and soon the musicians of the 1960s were incorporating the synthesizer and electronic sounds in general within their wider political and personal explorations into transgression, transcendence, and transformation. This was a two-way process: the synthesizer was in part shaped by 1960s psychedelia but it in turn helped shape the movement. Buchla, as I already mentioned, was the hippie's engineer, and it was he who first realized the power of the synthesizer in terms of the psychedelic movement's exploration of new washes of sound, new instruments, and ways to achieve that classic "spacey" sound and "spaced out" feeling. Buchla played his synthesizer with the Grateful Dead, Big Brother and the Holding Company, and others at a famous 1960s happening known as the Trips Festival. Soon other psychedelic groups like the Doors, the Byrds, and famously the Beatles, acquired synthesizers.

Other technologically mediated forms of cultural production and reproduction are important to the history of the synthesizer. In particular, the recording industry is crucial. We would never have heard of the Moog synthesizer if it were not for one of the biggest hit records of 1968, Wendy Carlos's Long Playing record *Switched-On Bach* performed on a Moog synthesizer. It was, and remains, one of the best selling Bach records of all time. It made Moog and his synthesizer famous and the LP cover showing a bemused wigged gentleman looking at a keyboard attached to a Moog synthesizer further reinforced the synthesizer as a keyboard instrument.[18] Other hit records followed as

[17] Although later Suzanne Cianni used her Buchla to make commercial sound signatures and became the Eric Siday of the 1970s.

[18] Ironically, the instrument shown on the cover could not be played live because of the lack of patch wires. Carlos's album was a studio achievement made with endless overdubs and by tape splicing of individual sounds. Despite its studio rendition the consensus was that Carlos made Bach "come to life."

the synthesizer became an indispensable part of "Progressive Rock" with Emerson, Lake and Palmer's use of the Moog to make their hit single "Lucky Man." A group called Hot Butter came up with their ubiquitous Moog hit, "Pop Corn."

Over time what we might call a "path dependence" for the keyboard synthesizer developed rather similar to the much better known path dependence of the QWERTY keyboard and the computer. "Lock-in" and "sunken costs" are the economists' terms for explaining this process (David 1985; Arthur 1988). I have argued elsewhere (Pinch 2001) that these terms need to be supplemented by a richer sociological vocabulary that describes how over time new pieces of technology, new processes of institutionalization, new markets, new users, new ways of doing things, and new sounds co-evolve.

Mediators and markets

Part of building the new institution of electronic music involved building a new market for synthesizers and synthesizer music. Economists often treat markets as matters of supply and demand. Instead our focus is upon how markets for technologies are actively constructed. In building markets, a key part is played by mediators like salespeople. It is salespeople who move between the world of use and the world of design and manufacture and who bring the two into alignment. We need to pay more attention to intermediaries such as salespeople and repair people. They are the missing masses of the sociology of technology. The role of salespeople in particular was crucial in marketing Moog's portable synthesizer, known as the Minimoog.

With the growing impact of the modular Moog in the recording studio, some synthesizer players started to experiment with live performance. The modular Moog was unsuited to this use; it was too big, too unstable, and too complex. It was also too expensive to become a popular live instrument.[19] In 1970 Moog and his engineering team solved these problems by developing the portable and cheaper Minimoog synthesizer. This is essentially a hardwired and simplified version with a keyboard built in. It retailed at around $1,500.[20]

The advent of the Minimoog was more than just a way station in the history of the synthesizer. The Minimoog also marked an important transformation in how synthesizers were sold. It signaled the dawn of a mass-market for synthesizers sold through retail music stores. The large modular synthesizers had been sold directly from the manufacturer. Moog employed two sales staff, one in New York and one in Los Angeles. The Minimoog was, however, sold in a completely new way to a totally new group of users.

The story here is somewhat similar to the history of George Eastman and the Kodak camera. Developing a cheap roll-film camera was not enough; Eastman had to find new users for his new technology (Jenkins 1997). In the process of recruiting

[19] A large modular Moog synthesizer and tape recorder could cost as much as $10,000—the price of a small house.

[20] This was affordable but was still the price of a rock van.

such users he transformed the institution of photography, turning it from an expensive high-end profession into something almost anyone could take part in. Part of this activity involved a transformation in how cameras were sold and marketed. A similar thing had to happen for the synthesizer to succeed and for the new institution of electronic music to take off. When Moog and his team of engineers developed the Minimoog they had no idea if there was a mass market for their instrument. It was a Moog user, appropriately enough a former television evangelist and novelty instrument demonstrator, David Van Koevering, who saw the potential of the new instrument for rock groups. It was he who devised ways of persuading young rockers to get into electronic music and to buy Minimoogs. His sales pitch was that it would give them the sonic energy that enabled the keyboardist to step into the limelight from the background, turning themselves into virtuoso "keyboard heros." Like the guitar heroes, they too could become stars. In the process, Van Koevering had to persuade retail music stores to stock synthesizers and build a sales network. Synthesizer salesmen started to attend the trade shows where most of the musical instrument business is carried out. Van Koevering was so successful that within a year he had become the vice president of the Moog music company and soon was selling synthesizers in music stores all over the world (Pinch 2003). At the same time the type of music played on the new portable synthesizer (including in particular "progressive rock") was marketed by record companies and further reinforced the synthesizer market.

Standardizing sound

The Minimoog was also important in terms of the evolution of electronic sound. By rejecting the patch wire approach of earlier synthesizers, the Minimoog in effect hardwired in certain sorts of sound. Sound was becoming more controllable and reproducible and at the same time more standardized. Van Koevering, in teaching rock musicians the new instrument, used colored tape on the different knobs and switches to mark specific sounds. Acoustic instruments could be emulated as never before and soon "sound charts" were devised showing the settings to make different sorts of standardized sound. This was not yet the digital age of MIDI or the perfect reproducibility of a preset sound available at the touch of a button or a click of the mouse, but what it meant was that electronic sound was becoming more stabilized and recognizable. The technology permitted certain sorts of sound to be produced and slowly over time users started to recognize and hear those sounds as distinctive features of the new electronic soundscape.

A good example here is the space-ship bypasses in *Star Wars*, one of the first movies to use a synthesizer for sound effects.[21] Soon the Star Wars space-ship bypass was recognized by everyone as the definitive space ship sound and other synthesists now had a name for the sound and it could be programmed into other

[21] It uses the ARP 2600 synthesizer for all the sounds including those of the robot R2-D2.

synthesizers.[22] This is the social construction of sound. The sound is recognizably that of a space ship; a new signifier in our world of sound.[23]

Agency and technology

How can case studies such as the one on the Moog help us build a sociology that takes materiality seriously? In dealing with materiality and specifically technology, I have suggested how approaches within the social construction of technology are helpful. In rethinking work on institutions and organizations we will have to rethink categories. In particular we need new ways to capture the agency that new forms of materiality afford. I suggest that we do not need to be quite as radical as sociologists of technology Michel Callon and Bruno Latour have suggested (Callon 1986; Latour 1987; Collins and Yearley 1992; Callon and Latour 1992; Bloor 1999; Latour 1999). They too want sociology to address material agency. Drawing on semiotics, they advocate a sociology of translations that for analytical purposes makes no distinction at all between humans and non-humans. In doing so, they must inevitably jettison most of conventional sociology. Organizations, institutions, social groups, networks, and identities are all useful terms but such terms have to be reworked and supplemented to take better account of materiality and the new forms of agency that technology affords. In thinking about the interaction between objects and actors around technology within institutions, we need new sorts of concepts.[24] I would like to conclude by suggesting a couple of concepts that I have found useful in my own research on the synthesizer.

The synthesizer can be described as a special category of object that in the field of sociology of science and technology is known as a "boundary object" (Star and Greisemer 1989). These are objects that cross boundaries between social worlds and can mean different things to actors in different social worlds.[25] For example, for psychedelic rock in the 1960s the synthesizer could be a means to enhance a state of altered consciousness, but for people working in the world of advertising a synthesizer was a new way of painting in sound, a way to conjure up a particular feeling to correspond to a particular product (the sound of Maxwell house coffee percolating or coke pouring).

The notion of a boundary object is rather static; it does not capture the agency that these objects permit. In my own work, I have been using anthropologist Turner's (1969) term "liminal entity" to capture the transformative powers of the synthesizer. Liminal entities, like boundary objects, are "neither here nor there; they are betwixt

[22] The story of this sound is actually more complicated as the synthesist, Ben Burtt, found the synthesized sound to be too weak and in the end used an electronically modified recording of a natural sound—that of the engine of a Goodyear blimp. See, Pinch and Trocco 2002 for the full story.

[23] This is a particularly interesting example because real space ship by-passes in space (a vacuum) should (according to physics) be completely silent.

[24] A related but less radical approach is that offered by Pickering (1995), who maintains a distinction between humans and non-humans in his theory of the "mangle."

[25] Boundaries are themselves socially constructed as actors engage in "boundary work" (Gieryn 1983). Gieryn (1999) generalizes the argument to examine the cultural boundaries of science.

and between the positions assigned and arrayed by law, custom convention and ceremony." The synthesizer is a liminal entity because it is something that can pass between different worlds, can take on different meanings in these worlds, and in the process transform these worlds. That is to say, with Bach played on the synthesizer we hear Bach in a new way. Psychedelic music played on a synthesizer transforms the ultimate user, the listener.

The actors in my study also morph their identities. Musicians on occasion turn into salesmen; engineers on occasion turn into musicians; and engineers can become salesmen. Transgressions are everywhere. This blurring of categories seems an integral part of the transformation I have been studying. When the modular Moog synthesizer was first used in recording studios, no one knew what to calls its operators: were they engineers, programmers, producers, musicians, or what? These actors crossed between different social worlds and changed identities as they went. I call these actors "boundary shifters." Bob Moog was a boundary shifter: a shaman who morphed back and forth between his engineering world and the world of musicians and in the process transformed the synthesizer. Boundary shifters work with liminal entities to cross boundaries to produce transformations in institutions.

In studying large-scale institutional changes in music like this one, we need terms that capture how technologies, actors, institutions, and organizations are transformed and at the same time are capable of exerting agency in the transformative process. Liminal entities and boundary shifters are two new categories for thinking about this double-edged sword of human and non-human agency.

I do not claim in this article to offer anything like a complete theory for thinking about technology and institutions. I see my contribution and the sociology of technology as helping to provide a set of tools that may or may not be useful in the study of organizations. Many ongoing organizational practices involve technologies.[26] The duality of structure and agency, and cognition and practice that has been fruitfully applied to many features of organizations must also be extended to the material realm. A technological standard such as the volt-per-octave standard established by Moog is a powerful reminder of this. The new standard is enabled by human culture and practices and in particular by a musical culture and set of practices that conceive of music in terms of octaves, but the new standard also constrains the sorts of musical practices we can engage in with synthesizers. We humans put agency into synthesizers and the synthesizers assert agency in constraining the sorts of music we can make. Synthesizers, like all technologies and all institutions, enable and constrain at the same time.

Institutional analysis has come a long way, but it must come further and at some point grapple with materiality and technology. The social world is a world built of things, social action is through and through mediated by materiality, and social theory will remain impoverished unless it addresses this materiality. I began my essay by asking whether technologies are institutions. The answer must be yes, but with a caveat—institutions themselves are made from things as well as people.

[26] The next stage in this project would be to tie these concepts more closely to the interests of neo-institutionalist organizational theorists in notions such as convergence, myths, loose coupling, etc. Material practices and technologies would seem to be important elements in institutional logics and how they change.

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