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"If I Could Turn Back Time": Occupational Dynamics, Technology Trajectories, and the Reemergence of the Analog Music Synthesizer*

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Abstract

There are numerous examples of the reemergence of old technology, such as vinyl records and film cameras. Yet, the literature on technology trajectories has focused almost exclusively on linear models of technology progression, and we have little understanding of the processes that may instead drive reemergence. In fact, no prior research has examined how users' occupational considerations may shape technology trajectories, despite a large literature on how occupations condition interactions with technological tools. This article sheds light on these processes through an inductive study of the music synthesizer industry's shifts from analog to digital and back to analog technology. Leveraging more than 40 years of data, we trace the relationship between technological developments and synthesizer players' occupational meaning. While synthesists initially embraced the ease of use and novelty of digital's black-boxed preset sounds, widespread adoption of digital sounds ultimately undermined musicians' occupational goal of distinctive creative expression. In response, synthesists articulated preferences for technology that afforded control, enabling them to use their expertise to create sounds, and that provided an embodied connection with the tool. Synthesists associated these affordances with analog rather than digital instruments, leading to renewed demand for analog and the reemergence of a formerly displaced technology. Our work integrates occupational considerations into the literature on technology trajectories, uncovers new mechanisms that can underlie technology reemergence, and extends the literature on occupations and technology.

Keywords: innovation, occupations, technological change, black boxing, expertise, music synthesizer

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* This article is part of a series of studies on the music synthesizer. The authors contributed equally.

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In 1987, a once-dominant music synthesizer producer, Sequential, went out of business—a victim of the titanic shift from analog to digital technology in the industry. Though Sequential had helped to establish the industry through its iconic Prophet-5 instrument, it was unable to survive this same industry's evolution. Sequential's analog contemporaries and the original industry leaders—Moog, Oberheim, and ARP—had already shut their doors. As one trade journal later put it, ''The era of the analogue polysynth seemed forever over'' (Reid, 2008: 20).

Yet today, demand for analog synthesizers among professional musicians is stronger than ever. For instance, Jack Antonoff—a member of the bands Fun and Bleachers and a collaborator with Taylor Swift and Lorde—relies heavily on analog synthesizers. Although Antonoff was just three years old when Sequential folded, he regularly uses the Prophet-5 in addition to numerous recently developed analog instruments. Antonoff is not alone. New analog synthesizers, many with original components, have been reintroduced by new entrants, established digital players, and reincarnations of some original firms, including Sequential. For the past several years, in fact, producers both old and new have introduced more new synthesizers based on analog than on digital technology. How do we account for this reemergence of a seemingly dead technology?

Models of technological change typically adopt a perspective in which successive generations continually improve along dimensions such as capabilities, features, and price–performance ratios. In some models, eras of technical variance and selection result in a dominant design, followed by faster, better, and cheaper iterations within this design (e.g., Anderson and Tushman, 1990; Suarez and Utterback, 1995). In other models, new, ''disruptive'' technologies that appeal to new segments emerge at the low end of traditional features and capabilities and grow to supplant existing options (e.g., Christensen and Bower, 1996: 202). In yet other models, technological evolution follows a less punctuated path, improving in gradual steps (e.g., Basalla, 1988). In each case, however, the image is one of continual improvement in capabilities and quasi-irreversible steps from old technologies to new ones.

Recent observations of the reemergence of old technologies, however, have suggested that such unidirectional models may not always fully and accurately reflect the adoption and use of technology (Raffaelli, 2019). We define reemergence as occurring when a previously displaced technology experiences substantial resurgent growth. This can occur within a meaningful niche or can characterize the dominant technology in an entire industry. For example, many professional disc jockeys have abandoned CDs for vinyl records (Tantum, 2021). Film cameras are now experiencing growth in some segments rather than further decline (Stummer, 2018). And even the lowly typewriter has been rediscovered as a coveted tool among professional writers (Sax, 2016). Although some research has pointed to old technologies retreating to niches where they persist (Adner and Snow, 2010) or reemerging as part of a different category that no longer competes with successor technologies (Raffaelli, 2019), research on technology reemergence remains scant.

Surprisingly, in fact, no prior research has examined how users' occupational considerations may shape technology life cycles and reemergence processes, despite a large literature on how occupations condition interactions with technology (e.g., Barley, 1986; Orlikowski and Gash, 1994; Leonardi and Barley,

2010; Mazmanian, 2013; Bechky, 2020). As this literature demonstrates, occupational members adopt and use technological tools to perform their jobs, and they interpret and interact with technologies through the lens of their occupations (e.g., Bechky, 2003; Nelson and Irwin, 2014). Presumably, these interactions could influence broad patterns of technology adoption and thus technology trajectories, too, though prior research in the occupational tradition has not investigated this possibility. Our article therefore explores the relationship between occupations and technology trajectories, with emphasis on understanding reemergence of technology.

We examine this relationship through an in-depth, inductive, historical study of music synthesizers and the professional musicians who use them. Synthesizers today serve a crucial role in most musical styles, ranging from hip hop to avant-garde jazz. Producers introduced the first commercial analog synthesizers in the late 1960s, and by the late 1970s, the industry was flourishing and supported dozens of firms. The introduction of digital synthesizers in the 1980s marked a major industry disruption, however, and by the late 1980s, production of analog synthesizers had largely ceased. Yet, as our opening vignette signals, significant demand for analog has rematerialized.

We find that the reemergence of analog technology resulted from musicians' ongoing negotiation of the relationship between their occupation's meaning—including their goals, practices, and expertise—and their technological tools: synthesizers. Digital synthesizers initially supported the occupation's goal of distinctive creative expression, even as they black boxed sound-creation practices and lessened the need for users' technical expertise. But the widespread adoption of digital synthesizers and their preset sounds soon undermined this goal, leading synthesists to express frustration with black boxing and to articulate a preference for technological tools that afforded more control and embodied connection. Synthesists perceived analog technology to have these affordances and, thus, to support their desired practices and expertise—ultimately leading to the reemergence of analog.

Our work holds several implications for theory. First, we integrate occupational considerations into the literature on technological trajectories by surfacing how black-boxed technology, which subsumes practices previously accomplished through interactions between users and tools, may constrain the use of expertise to achieve key occupational goals. This dynamic can lead to shifts in demand across technological generations. More generally, these observations reveal how occupations may not only respond to new technologies, as others have emphasized (e.g., Barley, 1986; Mazmanian, 2013; Nelson and Irwin, 2014; Bechky, 2020), but also shape technology trajectories. Second, we augment the technology life cycles literature by expanding on the conditions and processes that can underlie technology reemergence. In so doing, we highlight the role and importance of technology affordances, a perspective that emphasizes the interplay among the materiality, interpretation, and use of technology (Orlikowski and Scott, 2008; Leonardi, 2011; Faraj and Azad, 2012). Specifically, we illuminate how occupational members' increasing preference for analog technology that afforded control and embodied connection was a key driver of reemergence. Understanding this process thus complements scholarship on producer-driven reemergence processes that occur through redefinition (Raffaelli, 2019). Finally, we extend our understanding of how occupations themselves evolve, revealing how occupational members can use

technological shifts to define their occupation in a way that both differentiates it from other occupations *and* enables members to differentiate from one another. We thus show how occupations may both react to and shape technological changes and how these interactions may shift over time with different consequences.

THEORETICAL BACKGROUND

Technology Life Cycles

A long-standing tradition of scholarly research has examined the relationship between technology and industry evolution (e.g., Utterback and Abernathy, 1975; Abernathy and Clark, 1985; Clark, 1985). This body of work has suggested that the technology underlying an industry experiences evolutionary cycles of variation, selection, and retention, with new cycles sparked by technological disruptions. The nascent stage of an industry is characterized by broad experimentation to resolve uncertainty about which technologies will work, how fast they will improve, and what customers will value.[1] In the second phase, through a highly contested process (Rosenkopf and Tushman, 1998), the industry converges on a dominant design. This design represents both a particular technological solution (Utterback, 1994; Suarez and Utterback, 1995; Klepper, 1996) and cognitive convergence on product functionality (Kaplan and Tripsas, 2008; Benner and Tripsas, 2012; Grodal, Gotsopoulos, and Suarez, 2015). Next follows a period of path-dependent, incremental innovation along a technological trajectory that focuses on improving performance across well-established dimensions of merit (Dosi, 1982).

When the old technology's performance improvement reaches a point of diminishing returns, often illustrated by an S-curve (e.g., Sahal, 1985; Foster, 1986), firms—typically new entrants—develop and introduce new technology that provides a discontinuous improvement in price–performance. The cycle then repeats itself, with the new technology eventually settling on a dominant design and the old, seemingly obsolete (Tushman and Anderson, 1986) technology disappearing from use. Examples of this substitution pattern include the transitions from electromechanical to electronic cash registers (Rosenbloom, 2000), from mechanical to electromechanical to digital typesetters (Tripsas, 1997), from twisted-pair copper to fiber-optic communications (Eggers and Kaplan, 2009), and from circuit-switched to internet protocol (IP) telephony (Benner, 2010).

The substitution dynamic, however, is not necessarily smooth and straightforward. Notably, the old technology does not always "go gentl[y] into that good night" (Thomas, 1952: 13). Incumbent firms often increase investments in the old technology when it is threatened, resulting in performance improvements that can extend its competitive life and thus delay substitution (Gilfillan, 1935; Utterback, 1994; Tripsas, 2008). Old-technology products also can benefit from new-technology spillovers since it can take decades for one technology to substitute another (Cooper and Schendel, 1976; Taylor, 2010; Furr and Snow, 2015; Cohen and Tripsas, 2018). Finally, improvements to the old technology may be used to target specific customer segments for whom

[1] While we use the terminology of Anderson and Tushman (1990), these stages are similar to the three stages identified by Utterback and Abernathy (1975).

aspects of the old technology remain valuable, what Adner and Snow (2010: 1655) called a ''retreat strategy.'' For instance, the medical profession continued to use pagers long after the general public had switched to other mobile devices. Thus, although complete substitution of the new for the old is typical, small niches that continue to demand the old technology can remain relevant for long periods.

Despite dynamics that can extend an old technology's life, this body of research assumes that once a new technology takes over, renewed demand for the old technology does not occur. In other words, technology continually marches forward. And yet, in some cases, old technology products, such as vinyl records, film cameras, and typewriters, have made surprising comebacks, reemerging. As defined above, reemergence differs from a retreat strategy that, in the words of Adner and Snow (2010: 1657), ''is explicitly subtractive,'' meaning that demand persists in a niche (only). By contrast, reemergence signals growth either within a segment or, as with analog synthesizers, in the market as a whole.

The scant prior work on reemergence has attributed it to retro behavior or nostalgia in consumer markets (e.g., Styvén, 2010; Magaudda, 2011; Sarpong, Dong, and Appiah, 2016) or to producers' directed attempts to redefine a legacy technology as serving a different purpose and a different market. For example, illustrating the latter process, Raffaelli (2019) described how high-end Swiss watch firms reframed the mechanical watch as a luxury status symbol representative of art rather than a straightforward device for telling time.

Collectively, studies on spillovers between generations, retreat strategies, and reemergence have started to explore whether and when technology trajectories may deviate from the technology-marches-forward paradigm. Yet, the literature on technology trajectories has remained almost entirely disconnected from another set of studies—those that consider the relationship between occupational members and technology use. This omission is remarkable since many people interact with technology as a tool in the context of their occupations, and presumably, occupational considerations could shape technology trajectories.

Occupations and Technology

Occupations define and demarcate what their members do; for instance, investment bankers and consultants offer strategic advice (Alvesson, 2004; Anthony, 2021), medical professionals provide diagnosis and treatment (Beane, 2019; DiBenigno, 2020), and firefighters extinguish fires (Weick, 1993; Pratt, Lepisto, and Dane, 2019). More fundamentally, occupations are social entities that reflect shared meaning: a common understanding among members of work goals, practices, and expertise, including specific knowledge or skills (Van Maanen and Barley, 1984; Abbott, 1988; Bechky, 2003; Anteby, Chan, and DiBenigno, 2016). For many occupations, the ongoing use of technology is central to work practices aimed at achieving these goals. For example, engineers rely on computer-aided design software (Bailey, Leonardi, and Chong, 2010), scientists depend on lab equipment (Barley and Bechky, 1994; Knorr Cetina, 1999), and surgeons rely on medical devices (Zetka, 2001; Beane, 2019).

Underlying many studies of occupations and technology is a recognition that technology is not deterministic; instead, reflecting a core tenet from the

literature on social construction of technology (Pinch and Bijker, 1984; Leonardi and Barley, 2010), occupations can shape the interpretation and use of technology. For example, Orlikowski and Gash (1994: 174) used the term ''technological frame'' to capture how occupational considerations shape the way in which members make sense of a new technology. In their study, consultants and technologists in the same firm interpreted the same technology, Lotus Notes software, differently depending on their occupations and functional areas. Similarly, Gopal and Prasad (2000) found that teachers framed a new decision-support system by using familiar classroom terms. In these and other cases, therefore, occupational members interpret a new technology through their occupational lens (see also Mazmanian, 2013; Bechky, 2020).

In related work, scholars have explored how new technologies can prompt questioning and revision of occupational meaning. For example, in a series of papers on the introduction of new medical imaging technology, Barley (1986, 1990) found that this introduction was followed by a shift in role relations between radiologists and technicians, which influenced who interpreted patient scans. Similarly, Bailey and colleagues (2012) found that the introduction of simulation technology at an automobile manufacturer was followed by the split of simulation engineers into two new roles: simulation modelers and simulation analysts. Likewise, Nelson and Irwin (2014) reported that librarians initially did not interpret internet search technology as aligned with their occupational meaning and, thus, strove to differentiate themselves from the technology. Yet, librarians' ongoing interactions with the technology led their goals and practices to evolve, and the same technology became a central tool for the performance of key occupational tasks.

In these and other studies, scholars have thus emphasized the relationships that occupational members have with technological tools themselves and the consequences of these relationships. Given many of these studies' interpretivist perspective, they also offer special attention to a technology's affordances, that is, occupational members' perceptions about what the materiality of a technological tool enables (Hutchby, 2001; Leonardi, 2011; Leonardi and Vaast, 2017). In some cases, prior studies focused on the ways in which tools' affordances facilitate unique expertise and the acquisition of specialized knowledge. For example, in a study of investment bankers, Anthony (2021) discovered that how bankers interacted with their analytical technologies shaped the development of expertise. Similarly, Kaplan, Milde, and Cowan (2017) found that through the ongoing use of atomic force microscopes, scientists developed expertise in nanotechnology that enabled unique cross-disciplinary research.

Beyond expertise and specialized knowledge, studies also have revealed that technological tools can afford occupational members embodied connections, that is, skill underpinned by ongoing tactile interactions. For instance, in his seminal work on craft-based occupations, Sennett (2008: 158) described how violinists develop ''highly trained hands,'' whereby they experience the ''error'' of playing inaccurate and out-of-tune sounds in their fingertips. He noted similar patterns of relations between cooks and their knives. Scientists and laboratory technicians, too, have described the importance of ''having a feel'' for their ''instruments, materials, and techniques,'' which matter significantly for ''successful practice'' (Barley and Bechky, 1994: 100; see also Keller, 1983). Such embodied connections can even transform

occupational work. For example, in examining the introduction of laparoscopic surgery, Zetka (2001) revealed that surgeons' physical interactions with surgical equipment were intertwined with a reevaluation of surgical approaches.

Collectively, these studies have demonstrated that occupational considerations are a major influence on how people interpret and work with a technology. However, we have little understanding of how such occupational considerations may, in fact, shape technologies themselves and, specific to our research focus, shape technology trajectories. In this article, we thus explore the relationship between occupations and technology reemergence.

DATA AND METHODS

Setting

We study the evolution and use of the music synthesizer. Synthesizers are electronic sound-generating devices that are typically coupled with a musical-keyboard interface and are used to create a wide range of sounds, from emulations of acoustic instruments to unique synthetic textures (Pinch and Trocco, 2002). As musical instruments, synthesizers are tools for production in a cultural industry. At the same time, they are fundamentally technology products, too; synthesizer producers invest heavily in R&D, and as we explain below, changing technologies have been an important influence on the industry's overall trajectory. For example, Roland, a producer of both analog and digital instruments, spent over 6 percent of sales on R&D in FY21, which is comparable to leading technology firms (Roland Corporation, 2021).

Synthesizers are used by a subset of musicians called ''synthesists,'' ''keyboardists,'' or ''keyboard players,'' for whom the instrument is a central tool for their work.[2] Synthesists use synthesizers for a wide range of musical tasks, including live performance and studio recording, in almost every genre of music. Like other musicians, synthesists use their instruments to create music based on sounds produced through playing. Further, they strive for this music to showcase distinctive creative expression, thereby conveying their individuality (Peterson and Berger, 1975; Askin and Mauskapf, 2017; Faulkner, 2017).

Although some academic and industry research groups had previously built their own custom synthesizers, the commercial synthesizer industry began with products from a handful of startup firms in the late 1960s. By the late 1970s, the industry was flourishing and supported dozens of producers, including industry leaders Moog, Oberheim, ARP, and Sequential. Moog's ''Minimoog'' synthesizer, introduced in 1970 and manufactured until 1981, was particularly influential and became an icon of the analog synthesizer era.

The 1980s ushered in a new generation of synthesizers as digital technology came to replace analog. While a few small firms attempted to commercialize digital synthesis in the late 1970s by introducing limited-production, high-end instruments, Yamaha's introduction of the DX7 digital synthesizer in 1983 marked a major disruption to the mainstream synthesizer industry. The DX7 offered a range of new sounds, was easier to use, and, unlike the earliest digital synthesizers, was priced competitively. It quickly became the best-selling synthesizer at the time (Nelson, 2015). Other producers soon followed with their own digital offerings. While larger diversified firms like Yamaha could fund

[2] We use the term synthesist for consistency, though other terms appear in our primary data.

the expensive up-front investment in custom computer chips required for digital and the company successfully transitioned, most of the focused analog producers quickly faltered. By 1987, the last major analog producer, Sequential, had gone out of business.

Digital and analog instruments differ in key respects. Most fundamental, analog synthesizers use electronic components to directly generate changes in voltage that create a sound wave; digital instruments, by contrast, use a computer that generates a stream of discrete 0s and 1s that are then converted to sound. The instruments, as a result, produce qualitatively different kinds of sounds, though analog and digital synths can also attempt to mimic each other. In fact, in the mid-1990s producers introduced digital ''analog modeling'' or ''virtual analog'' synthesizers that directly mimic the behavior of analog circuits.

Most analog machines also feature numerous different knobs corresponding to different signal-generating parameters, which musicians use to generate and modify sounds. Since many analog machines have no memory, users have to manually change these knob settings to create new sounds (and to recreate previously used sounds). Digital synthesizers, by contrast, black box sound creation, relying heavily on ''presets,'' or pre-programmed sounds that are stored in memory. A musician selects these sounds by pressing a button or by making a selection from an LCD display menu that conveys information such as the preset number and name.

As our opening vignette signals, although analog did largely disappear from production by 1987, the late 1980s did not mark the end of analog. In fact, today the majority of new synthesizers use analog technology, and most digital instruments now emulate analog sounds and include analog-inspired interfaces. Thus, the synthesizer industry represents an ideal setting in which to explore the reemergence of a technology presumed to have died.

Data Sources

Our primary data source is *Keyboard* magazine, which ran monthly print issues from 1975 until 2016, making it the leading and longest-running trade journal for synthesists. (In 2017, *Keyboard* shifted to an online-only format.) *Keyboard* enabled us to capture the perspectives of both occupational members (via published interviews with synthesists) and producers (via their advertisements for synthesizers). Notably, the magazine also serves as a forum for users and producers to connect and to exchange ideas (Kahl and Grodal, 2016). For example, letters to the editor from producers, in response to magazine content, signal that these firms not only advertised in *Keyboard* but also read it.

Interviews.

Keyboard staff frequently interviewed synthesists, which allowed us unique insight into these occupational members' perspectives over time. We examined every interview in every issue from 1975 through 2016. Since we were interested in musicians' reflections on synthesizers, e.g., how they used them and why they chose particular synthesizers (analog or digital), we included only interviews that had commentary on these topics, a total of 476 over the 42-year period. Interviewees included synthesizer players with leading musical acts of the time as well as lesser-known professionals, covering a wide range of genres. Nearly 40 percent of interviews from 2001 through

2016 were with musicians born after 1970, in other words, individuals who would not have used analog synthesizers before digital rose to prominence.

The use of published historical interviews as a data source offers many advantages (Nelson, 2017). First, these interviews circumvent concerns about retrospective bias since they capture interviewees' contemporaneous reflections. Second, because we did not develop the interview protocols or conduct the interviews, our use of these materials prevents the objection that we phrased questions with a particular response or objective in mind. Third, the use of published interviews enables us to identify names in ways that our universities' Institutional Review Board guidelines might restrict had we conducted the interviews ourselves. Finally, from a pragmatic perspective, the use of these interviews enables us to draw on insights from many more individuals than we could have reached ourselves.

To supplement these historical interviews, we also conducted nine interviews in 2021 with additional synthesists who first encountered analog instruments during the reemergence period. These interviews enabled us to further compare themes across generations within the occupation and to probe more deeply into how occupational members interpreted and used different synthesizer technologies. We also were able to triangulate our findings by engaging in observation and informal interviews at industry conferences, including general gatherings such as the National Association of Music Merchants (NAMM) trade show and conferences focused on the synthesizer industry such as Moogfest, Voltage Connect, and KnobCon.

Advertisements. To understand how producers positioned and framed their synthesizers and which features and qualities they highlighted, we captured advertisements placed in *Keyboard* magazine. Every major synthesizer producer placed frequent advertisements in the magazine. Because *Keyboard* targeted professional musicians and not hobbyists, these ads also are aimed toward professional musicians. Thus, *Keyboard* almost never contained ads for consumer-oriented keyboards, which tend to be low cost and to have features like built-in speakers that are unimportant to professionals (who use professional-grade studio monitors and/or PA equipment), and we do not include such instruments in our analysis.

Because we focus on the reemergence of analog, we began by capturing every ad for a synthesizer that appeared in the January or July issue of *Keyboard* each year from 1987 (when the last analog producer disappeared) through 2016. We did not detect any systematic difference between the January and July ads and thus did not add months to our dataset. Then, to provide a comparison with earlier periods, we also captured every January ad from 1976 through 1986. (*Keyboard* started in August 1975.) In total, our data include 680 ads.

Archival documents and websites. To complement the data from *Keyboard*, we assembled a global database of all synthesizer producers and synthesizer product offerings from industry inception through 2019. We assembled these data from a combination of synthesizer-enthusiast websites such as VintageSynth.com; company websites, including historical capture from archive.org; and industry books and reference guides such as Colbeck (1997),

Vail (2014), and Jenkins (2020). For each model we captured the producer; product name; introduction date; sound generation technology (analog, digital, digital with analog modeling); and features, including whether the model had knobs/sliders and memory (the ability to store sounds). For each producer we captured firm background (e.g., startup or diversifying entrant), home country, and, drawing upon our product data, the years in which the firm manufactured each type of synthesizer (analog, digital, digital with analog modeling). In sum, this database consists of a total of 1,203 models from 162 producers.

Finally, NAMM provided us with data on the industry more broadly, such as overall category sales and commentary on industry trends. Table 1 provides an overview of our data sources and how they informed our analysis.

Analysis

Because of the lack of theory addressing occupations and technology reemergence, we chose inductive, historical methods for our analytical strategy (Eisenhardt, 1989; Edmondson and McManus, 2007). Thus, we took an interpretivist and contextually informed approach to longitudinal data analysis (Kirsch, Moeen, and Wadhwani, 2014; Wadhwani, 2016; Wadhwani et al., 2020). We began by reading through all of our data—interviews, advertisements, articles, trade reports, and books—chronologically, and we developed a timeline of major events, such as the introduction of the Yamaha DX7, the bankruptcies of various producers, the introduction of the first analog model in the reemergence period, and so on. We also examined the descriptive statistics from our data, such as the overall pattern of analog versus digital product introductions over time. This exercise helped us to understand the synthesizer industry, including different firms, pivotal events and products, major themes, general trends over time, and key differences between analog and digital technologies.

Building on this exercise, we divided our data into five phases: Analog Emergence, focusing on the 1970s to the early 1980s when the synthesizer industry—and occupation—was first established; Digital Disruption, focusing on the immediate introduction of and reactions to digital from the early to mid-1980s; Digital Dominance, focusing on the period from the mid-1980s to the early 1990s, when digital synthesizers were the most prevalent offerings in the market; Digital Imitation of Analog, when producers modified digital instruments to mimic analog from the 1990s to 2000s; and finally Analog Reemergence, focusing on the period from the early-2000s to today, when analog synthesizers grew to be commonplace again. We based these phases on a combination of market trends (e.g., which technologies were most prevalent in a period), key product dates (e.g., the introduction of the DX7 in 1983), and key industry events (e.g., the disappearance of the last analog producer in 1987), though we acknowledge that each of these phases is fluid, and as expected in a rich historical setting, our selected dates do not cleanly bracket themes from each period.

Because interpretation is important in technology adoption and use, we then sought to understand synthesists' reflections and producers' claims in each phase. To start, we open-coded interviews with synthesists. This analysis revealed the salience of occupational considerations for synthesists in discussing how they approached their tools and work. In particular, synthesists

Table 1. Description of Data

Data Type	Date Range	Amount / Location	Use in Analysis
Primary data			
Interviews with musicians in *Keyboard* magazine	1975–2016	476	Provided insight into musicians' choices and preferences regarding synthesizers, their use cases for different models, and their views on analog and digital synthesis more broadly
Interviews with musicians conducted by author team	2021	9	Provided insight into musicians' choices and preferences regarding synthesizers and their views on analog and digital synthesis more broadly
Synthesizer producers' product advertisements in January and June issues of *Keyboard* magazine	1976–2016	680	Provided insight into how synthesizer producers framed models, including their sounds, interfaces, and other features
Model specs for every synthesizer, including features, year produced, list price, years manufactured, and producer. Collected from *Keyfax*, websites like vintagesynth.com, and firm data	1963–2019	1,203	Established when synthesizer models were being released over time
Firm characteristics for every manufacturer, including background, home country, and years active in synth technology. Collected from industry publications and company websites	1963–2019	162	Established manufacturer entry and exit patterns across synthesizer technologies over time
Observations at industry conferences, including NAMM, Voltage Connect, Moogfest, and KnobCon (5 in total). Enabled informal conversations with industry insiders (~25)	2017–2022	Anaheim, CA Boston, MA Durham, NC Chicago, IL	Informed our understanding of perspectives and values of analog and digital synthesis. Allowed us to vet and refine our emerging findings
Secondary data			
Synthesizer sales data and commentary on industry trends from NAMM	1973–2016	44 reports	Informed our understanding of industry growth and evolution
Books written by industry insiders and enthusiasts about the history of the synthesizer	1986–2019	8	Informed our understanding of the evolution of synthesizer technology, its use, and the industry more broadly

shared that their technology use was entwined with occupational meaning, that is, work goals, practices, and perceptions of requisite occupational expertise. For each of the phases noted above, we thus coded three factors: 1) whether synthesists perceived their technological tools as supporting their occupational goals; 2) what occupational practices supported those goals, specifically, whether synthesists were playing ''synthy'' sounds (i.e., sounds that only a

synthesizer could produce) and/or emulations of acoustic instrument sounds; and 3) what level of technical expertise was associated with the occupation. For example, Mitchell Froom, who worked with Suzanne Vega and Crowded House, among other bands, commented in a 1993 interview,

> I walked through a music store recently and went from synthesizer to synthesizer in search of anything that might be even vaguely inspiring, but it all sounded like endless variations on the same bad [digital] chip. These synths have no overtones, no eccentricities, no uncontrolled distortion. They have all the appeal of a room filled with powder-blue leisure suits. . . . There's nothing to respond to, nothing to lean on, nothing to help express individuality.

We coded this passage as reflecting Froom's perception that the digital instruments he encountered did not support the occupational goal of distinctive creative expression.

Sometimes, interviewees reflected on more than one construct in an interview. For example, Grammy-winning synthesizer soloist Wendy Carlos commented in a 1979 interview,

> [Some] musicians who really don't learn the instrument idiomatically but who have backgrounds as pianists take it on, and that's not quite kosher. It's not really fair to call yourself a synthesist in that case. With other instruments it's more obvious: If you're an accordionist and you pick up a violin, you're not going to record on it in the first year, are you? To call yourself a violinist at that point . . . Maybe now I sound too puristic. It's hard to know where to draw the line for artistic integrity. I do feel, though, that if you're going to call yourself a synthesist, you have to have some familiarity with the instrument. . . . timbre changes, changing the pulse width, adding a little bit of vibrato, changing the vibrato rate.

We coded this passage as reflecting on both practices and expertise: Carlos believed synthesists ought to create unique synthy sounds (not just emulations of other instruments) and felt that synthesists should have specialized technical expertise.

In addition to noting reflections on occupational meaning, we observed that in later periods, synthesists began to discuss their preferred affordances, specifically, a desire for control and for embodied connection. We therefore coded whether interview statements reflected these affordances. We coded a statement as referring to control if the interviewee commented on whether a synthesizer enabled them to directly modify, program, or control sounds. We coded a statement as referring to embodied connection if the interviewee commented on a tactile and physical interaction. Of course, sometimes statements reflected both sentiments. For example, Gobber shared in a 1996 interview, ''The beauty of analogs is that they're a lot more hands-on. The controllability is at your fingertips.'' We coded this passage as reflecting the importance of both control and embodied connection with an instrument.

In parallel, we coded producers' advertised claims about their products—including features, characteristics, and usage—in order to analyze how they framed synthesizers to appeal to musicians. We began by open-coding the advertisements. Given what we knew of the differences between analog and digital synthesizers, we focused our coding on references to interfaces, sounds, and claims about use. For product interfaces, we coded whether the

ad emphasized having an abundance of knobs/sliders or smooth panels with push buttons and a digital display. For coding sounds, we focused on two dimensions: whether an advertised product was described as making 1) imitations of acoustic instruments and/or 2) new synthy sounds. In addition, we traced whether synthy sounds were associated with analog or digital instruments. To do this, we created a dictionary of adjectives associated with analog versus digital sounds, based on our initial review of the industry and associated trade books (Vail, 2014; Jenkins, 2020). Analog adjectives included words such as ''gritty,'' ''warm,'' ''round,'' ''dirty,'' and ''fat.'' By contrast, digital adjectives included words such as ''sparkly,'' ''clear,'' ''crystally,'' ''clean,'' and ''bell-like.'' We also coded producers' claims about how synths could be used, including whether they emphasized presets and ease of use or knobs and control.

During this coding, we noticed that producers' framing did not always align with the technical features of the advertised models. We therefore drew on our analysis to code whether each advertisement was appealing to an analog or digital frame. If an ad emphasized analog synthy sounds and/or a tactile, knob-based interface, we coded it as having an analog frame. If it emphasized acoustic emulations, digital synthy sounds, and/or presets, we coded it as having a digital frame. In the case of advertisements that had very little information, such as a simple picture of a loudspeaker with the name of a forthcoming synthesizer, we coded the ad as having no frame. Each author individually coded a subset of advertisements, and then all three authors reviewed all the coding and held discussions to resolve borderline cases. See Figure 1 for examples of advertisement coding.

To analyze whether and how these themes resulted in shifting patterns in the technology life cycle, we then looked at patterns of occupational reflections (in the interviews), producers' rhetoric (in the advertisements), and interactions between them over time and across phases, as well as what triggered shifts in these patterns. For example, we noticed that reflections on embodied connections with instruments emerged only after the late 1980s, and that sound references shifted from a mixture of acoustic imitation and synthy in the 1970s and 1980s to almost entirely synthy in the 1990s and later. In addition, we noticed that the meaning of certain characteristics of synthesizers changed over time. For example, in earlier years, synthesists critiqued the tendency of analog synths to go out of tune, while in later years they suggested that this same tendency was a desired and distinguishing feature. We thus went back and coded the changing interpretations of particular instruments and characteristics and, again, assessed patterns over time. We examined patterns leading up to these key shifts to help deepen our theorizing. Ultimately, we assembled these different elements into an integrated model of how technology and occupations co-evolve and can result in reemergence.

FINDINGS

We found that the reemergence of analog technology resulted from musicians' ongoing negotiation of their occupational meaning—including goals, practices, and expertise—and its relationship with their technological tools: synthesizers. Both analog and early digital synthesizers offered novelty that supported synthesists' occupational goal of distinctive creative expression. However,

Figure 1. Examples of Advertisement Coding

Model	EMU Proteus MPS Plus	Korg MS2000
Year	1992	2001
Technology	Digital	Digital
Interface	Pushbutton, menu-driven	Knobs
Sounds: Acoustic emulation vs. synthy	Acoustic emulation: "sounds like grand pianos, screaming electric guitars, punchy brass. . . solo strings, woodwinds, classical brass and orchestral percussion . . . a full symphony orchestra at your fingertips"	Synthy: No mention of acoustic sounds "meaty analog sounds"
Sounds: Digital vs. analog	Digital: "studio quality digital effects"	Analog: "meaty analog sounds"
Claims about use	Emphasize presets andease of use: "the ability to access 500 onboard presets. . . all with the industry's clearest, most straight-forward user interface" "More easy-to-use features"	Emphasize knobs and control: "knob-packed interface harken[s] back to a day when synths invited you to shape your sound as you played"
Framing	Digital	Analog

digital synthesizers also black boxed sound creation with preset sounds. As digital became widely adopted, musicians thus found it more difficult to meet their goal of distinctive creative expression; they became frustrated by the inability to create and manipulate their own sounds and expressed desire for a technology that afforded them control as well as embodied connection—in other words, a return to analog. Our findings therefore highlight the tradeoffs associated with technological advances that black box key occupational practices and limit the use of expertise.

In the following sections, we unpack how this process unfolded across the five phases of the synthesizer's evolution: Analog Emergence, Digital Disruption, Digital Dominance, Digital Imitation of Analog, and Analog Reemergence. For each phase, we describe producers' technical product

choices and how they were framed; how occupational members interpreted these offerings, including whether the technology enabled synthesists to meet their occupational goals and how that influenced subsequent adoption behavior; and how adoption and use shaped occupational practices, technical expertise, and eventually users' articulation of desired affordances. We then cycle back to producers' technical product choices in response to occupational feedback. Figure 2 provides a visual representation of the interactions among producer actions, occupational meaning, and user actions across phases, and Table 2 summarizes our findings across the phases. For purposes of exposition, our narrative breaks out the relationships among producer actions, occupational meaning, and user actions in a linear fashion. Yet, as is typical with historical studies, interactions were ongoing and iterative across phases, and the movement between phases was gradual, without clearly demarcated boundaries.

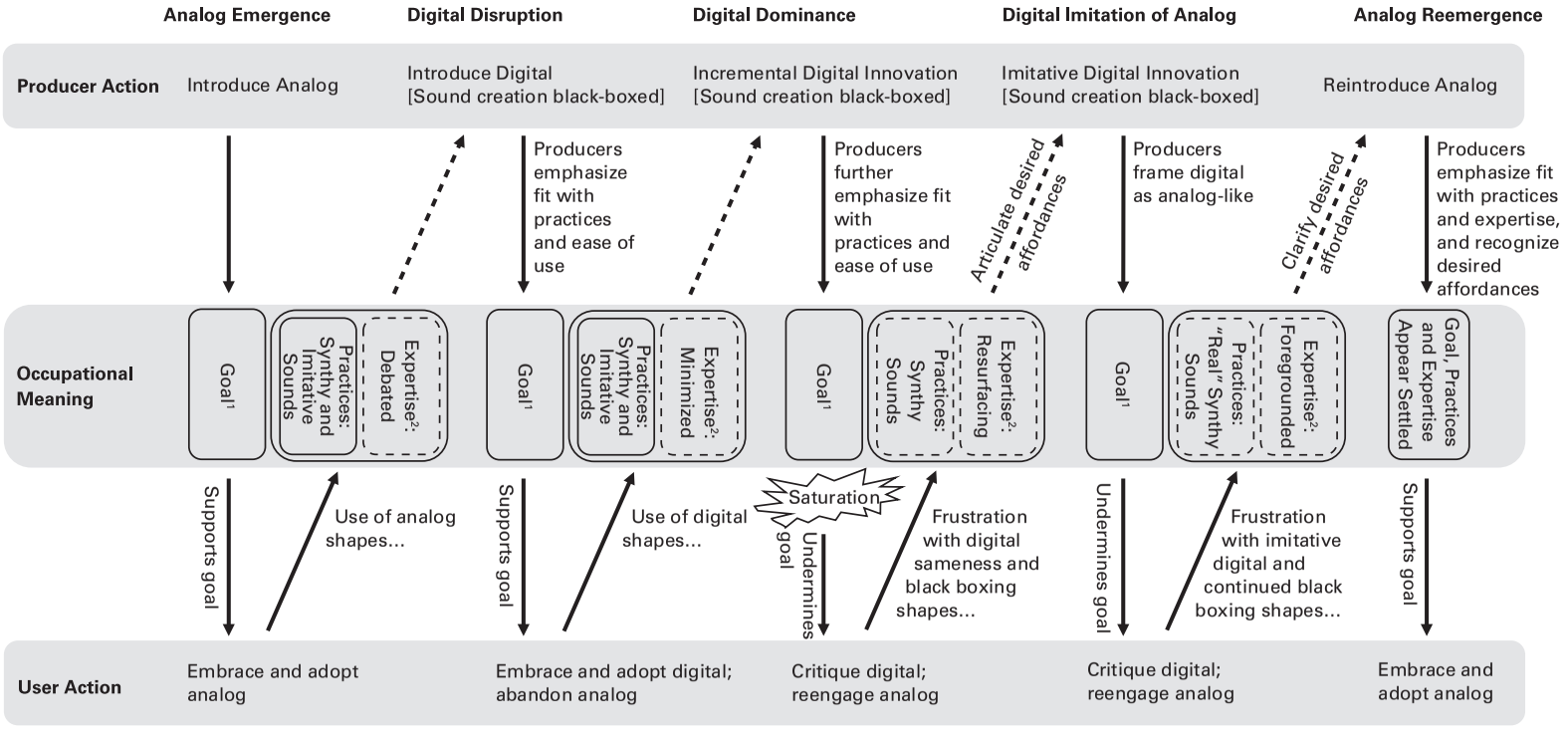
Analog Emergence (1970s to Early 1980s)

Producers introduce analog synthesizers. When producers introduced the first analog synthesizers in the late 1960s and 1970s, they positioned them as both new instruments that played novel synthy sounds and as acoustic emulators that recreated acoustic instrument sounds (Anthony, Nelson, and Tripsas, 2016). Advertisements for early synthesizers highlighted these different potential applications. For example, a 1977 ad for the Polymoog emphasized ''the almost limitless electronic sound potential of a Moog synthesizer.'' By contrast, a 1977 ad for the ARP Omni emphasized the imitation of acoustic instruments: ''[The Omni is] symphonic, able to produce authentic strings, brass, piano, harpsichord, and vibes.''

Accompanying the emergence of synthesizers was the emergence of the synthesist occupation: professional musicians who created music using a technological tool, the synthesizer. Since, by definition, synthesists played synthesizers, not only musical objectives but also the emerging use of analog synthesizers influenced their emerging goals, practices, and expertise—or occupational meaning.

Common occupational goal: Distinctive creative expression. Synthesists shared with professionals in many musical occupations a broad occupational goal of distinctive creative expression (Faulkner, 2017). As Jan Hammar explained in 1976, ''I was searching for an expressive melodic instrument and the synthesizer was perfect. . . . Synthesizers gave me a new lease on musical life. . . . Once you get down to serious business with the synthesizer, you realize that the possibilities are endless.'' Similarly, in 1982, Andy McCluskey of the band Orchestral Manoeuvres in the Dark said that ''the whole idea behind synths is the freedom they have the potential to generate. . . . Since theoretically each one has so many possibilities, you can use them to make your own noise.'' That same year, Doug Johnson, too, emphasized the importance of having a distinctive sound: ''If somebody tells me, 'Jeez, that sounds an awful lot like so-and-so,' then I'll try to change what I'm doing.'' In short, synthesists rapidly agreed on the broad goal of their new occupation and experienced analog synthesizers as supporting this goal. Table 3 provides additional evidence of this relationship.

Figure 2. Summary of Interactions Among Producer Actions, Occupational Meaning, and User Actions Across Phases



[1]Synthesists' goal of distinctive creative expression remains consistent over time

[2]Synthesists always rely on musical expertise. This label refers to changing beliefs around the role and importance of technical expertise

Table 2. Summary of Occupational Meaning, Desired Affordances, and Technological Fit Across Phases

Phase	Analog Emergence 1970s to Early 1980s	Digital Disruption Early to Mid-1980s	Digital Dominance Mid-1980s to Early 1990s	Digital Imitation of Analog Mid-1990s to 2000s	Analog Reemergence Early 2000s to Present
Occupational meaning					
Goal	Distinctive creative expression	Distinctive creative expression	Distinctive creative expression	Distinctive creative expression	Distinctive creative expression
Practices	Unsettled • Play synthy sounds and/or emulate acoustic instruments	Unsettled • Play synthy sounds and/or emulate acoustic instruments	Narrowing • Play synthy sounds	Narrowing • Play analog-like synthy sounds	Settled • Play "real quirky" analog synthy sounds
Expertise*	Unsettled • Musicians diverge on whether technical expertise should be important for synthesists	Minimized • Technical expertise not necessary to be a synthesist	Resurfacing • Belief that technical expertise is important for synthesists reemerges	Foregrounded • Belief that technical expertise is important for synthesists solidifies	Settled • Synthesists need technical expertise to create sounds
Relationship between technology and occupational goal	Analog supports occupational goal • Synthesists achieve distinctiveness by using expertise to create and play their own unique synthy and acoustic emulation sounds	Digital supports occupational goal • Synthesists achieve distinctiveness by playing novel preset synthy and acoustic emulation sounds	Digital undermines occupational goal • Synthesists cannot achieve distinctiveness playing digital synths because preset sounds are saturated and no longer novel	Digital emulation of analog undermines occupational goal • Synthesists cannot achieve distinctiveness playing digital synths since preset analog-emulation synthy sounds are not novel	Analog supports occupational goal • Synthesists achieve distinctiveness by utilizing technical expertise to create and play their own unique synthy sounds
Desired technology affordances	Unarticulated	Unarticulated	• Control • Embodied connection	• Control • Embodied connection	• Control • Embodied connection

* Musicianship is an element of occupational expertise throughout. This row refers to perceptions about the role of technical expertise.

Unsettled occupational practices. Although synthesists shared a common goal, in this early period they varied in their perception of the practices that should underlie this goal. Although analog synthesizers enabled users to both create new synthy sounds and emulate the sounds of acoustic instruments, synthesists were divided on which practice should define the profession. Some believed that synthesists should strive to imitate the sounds of other instruments. Richard Barbieri of the band Japan reflected in a 1982 interview, "We try to make almost every single sound as acoustic as possible. . . . I much prefer the sound of traditional instruments. We're merely using synthesizers to create that." By contrast, other synthesists shared that the synthesizer—and thus synthesists—should create new synthy sounds of their own. Solo artist Klaus Schulze described in a 1983 interview how "every instrument has a purpose. The synthesizer was not made to replace an orchestra. You would never try to copy a violin with a guitar. The synthesizer is an independent instrument, and should be played that way."

Unsettled occupational expertise. Synthesists also were divided on the nature of technical expertise that being a synthesist should require. All

Table 3. Additional Evidence of Relationship Between Technology Use and Occupational Goal Across Phrases

Analog Emergence	Digital Disruption	Digital Dominance	Digital Imitation of Analog	Analog Reemergence
Analog technology supports goal: "With an instrument that's about as unlimited as any instrument can be, I think there's more that can be done on the creative level. That's what I'm aiming for." (Edgar Winter, 1976) Interviewer: "Why did you get into using [analog synthesizers]?" Franke: "We were looking for a way to make a new impression. We wanted to stretch the imagination. We wanted to create sounds that your mind didn't help to fill in." (Christoph Franke, 1981)	Digital technology supports goal: "I fell in love with the sound of the PPG [digital]. It has such a rich original sound." (Geoff Downes, 1983) "Instead of hiring a whole trumpet section, I can mix one or two trumpets with the synthesizers to get the sound I want . . . I've fooled trumpet players into thinking that they were hearing a trumpet section when it was something I was playing on a synthesizer." (Herbie Hancock, 1983)	Digital technology undermines goal: "Everybody's using that breathy sound [on the Roland D-50 digital synth], so I can't . . . it doesn't have my signature on it." (David Bryan, 1988) "It would be very simple for me to write for a bunch of DX7s, because I could get those anywhere, but then it wouldn't sound like me. It wouldn't sound like the music's supposed to sound." (Lyle Mays, 1986)	Imitative digital technology undermines goal: "You can switch on a modern keyboard as well, and find the right sound, but usually the presets are so generic, and you hear them so often." (Nick McCarthy, 2009) "Because of the availability of all this new [digital] technology, there's thousands of guys around the world who have access to the same stuff. So it's less interesting to me now. It's sort of like the difference between Doctor Livingston exploring Africa, and going on a safari today where there are Land Rovers left, right, and center [laughs]." (Thomas Dolby, 2011)	Analog technology supports goal: "I'd rather get my hands on some crazy old vintage analog synth. It's never exactly the same twice, but that makes you sculpt the sound in real time instead of flicking through 500 presets . . . for me on this record, I had the ideal sound in my head and the only way to get it was [analog] synths." (Scott Hardkiss, 2010) "There's a uniqueness to analog sound that you cannot match with a digital synth. There is a power to it, a feeling of a life force behind these sounds . . . Whether it's just the fluctuation in electricity that's creating them, it's amazing." (2021 interview)

synthesists had musical expertise. But unlike other keyboard instruments such as the piano and harpsichord, which even a novice can strike to make a sound, early analog synthesizers required musicians to create their own sounds. In turn, this required deep technical understanding of how the instrument shaped sound, and entailed a sort of programming by manually adjusting different sound parameters, typically with physical knobs.

Although playing analog synthesizers required technical expertise, musicians differed on whether they believed this expertise *should* be an important component of occupational meaning or, instead, constrained musical expression. On the one hand, musicians such as John Simonton embraced technical expertise as a key dimension of the occupation, noting that "a person who wants to effectively utilize a synthesizer has to be a musician, but also a physicist. The synthesizer's proper use depends a whole lot on whether the individual using it understands the physics of the sound he or she is trying to produce" (1979). Indeed, when discussing their instruments, musicians often referenced the technical aspects of sound creation. For instance, Tom Coster explained how being able to manipulate the instruments' oscillators enabled valued sounds: "The oscillators [in my Minimoog] sweep against each other very nicely. For my own taste, that phasing and grinding you get from the two oscillators beating against each other is almost like having a flanging effect" (1982).[3] On the

[3] Flanging occurs when one audio signal is accompanied by an identical but slightly delayed second audio signal, generating a richer harmonic sound.

other hand, some synthesists were frustrated by the level of technical expertise required to play analog synthesizers, and believed it should not be required to play the instrument. Steve Winwood reflected in a 1981 interview, ''To me, these [synths] are the greatest things around. I would very much like to concentrate more on synths, but I don't like to get buried in books about electronics.'' Table 4 offers additional evidence of synthesists' reflections on occupational practices and expertise.

Digital Disruption (Early 1980s to Mid-1980s)

Producers introduce digital, emphasizing fit with practices and ease of use. Guided by a desire to improve upon analog, producers developed and introduced the first digital synthesizers in the early 1980s. Consistent with the occupation's unsettled practices, producers emphasized both the novelty of digital synthy sounds and the realism of acoustic imitations in their advertising. For example, a 1985 ad for the Korg DW-6000 claimed, ''the introduction of digital synthesizers [has] ushered in a whole panorama of new and complex sounds not previously available on conventional synths. . . . [The DW-6000] integrates the complex and interesting sounds of digital technology.'' In addition, a 1983 advertisement for the Casio CT-405 stated, ''From trumpet to clarinet, from piano to pipe organ. Sounds so authentic that if smoke got in your eyes, you might swear you were hearing the real thing. What makes it possible is Casio's advanced digital sound.'' Similarly, a 1984 ad for the Yamaha CE20 read, ''Introducing the true sound of a trumpet, clarinet, oboe, electric piano, cello, piccolo and 16 other instrument voices. . . . The reason for all the voice authenticity is simple: FM digital technology.''

Digital synthesizers also were easier to use than analog ones since producers black boxed the creation of sounds, pre-programming digital instruments with numerous preset sounds that were stored in memory and could be accessed via push buttons and/or from display menus. Thus, musicians who lacked technical expertise could easily play digital synthesizers. Producers promoted this improved ease of use to synthesists. For example, a 1984 advertisement for the Yamaha CE20 claimed, ''The technology itself is not simple. But getting the voice you want is. Just press a button. No complicated control settings, no hassles. Just true acoustic sound.'' Similarly, a 1986 ad read, ''If you can press a button, you can call up any of the Kurzweil 250's 45 resident voices.'' Table A1 in the online appendix provides additional examples of producers' claims during the period of digital disruption.

Digital innovation supports occupational goal. Synthesists were attracted to these digital instruments because they produced new and seemingly better sounds and thus enabled the occupational goal of distinctive creative expression. For example, Jeff Lorber noted in a 1984 interview, ''In general, digital sounds have more high end and they cut a lot more. Because of that, they're overall more sparkly. They have more presence, more clarity, more definition; for me, they're just more exciting and interesting.'' Similarly, in a 1985 interview Kashif reflected on why he bought the Yamaha DX7 digital synthesizer: ''It's the easiest to get a wide array of sounds, the most expressive, and the quickest to be expressive.''

Table 4. Additional Evidence of Occupational Practices and Expertise Across Phrases

Phase	Analog Emergence	Digital Disruption	Digital Dominance	Digital Imitation of Analog	Analog Reemergence
Practices	Unsettled Play synthy sounds: ''Even though it has the ability to sound like other things, the synthesizer is very much an instrument unto itself, and I try to approach it as such.'' (David Sancious, 1977) Acoustic emulation: ''What I'd really like to see in a keyboard instrument is a good simulated orchestra sound.'' (Peter Sears, 1976)	Unsettled Play synthy sounds: ''We've structured the sounds to incorporate many light timbres from the DX7s. . . . They give us that real bell lightness we get on the album.'' (Tony Kaye, 1984) Acoustic emulation: ''I'll tell you, the best string sounds are in the Emulator and the Fairlight. They are the most realistic. The Fairlight sound is especially marvelous; the low string is one of my favorite sounds in there.'' (Nick Rhodes, 1984)	Narrowing Play synthy sounds: ''The thing I like about synthesis is the ability to do things which cannot be done any other way. I've gone away from the idea of imitative synthesis. My feeling is that the stage to reach is innovation, where you're creating things with the synthesizer that can't be done on other instruments.'' (Malcolm Cecil, 1984)	Narrowing Play real analog synthy sounds: ''I have an affinity for true analog synthesized sounds, which probably comes from the influences of 'kraut rock' and disco. I like the warmth of that sound.'' (Beans, 2003)	Settled Play real analog synthy sounds: ''They [analog sounds] have character. They have noise, because they're coming out of a real machine. And they never sound the same twice.'' (Wilhelm Leeb, 2010)
Technical expertise*	Unsettled Expertise is important: ''The technical skill now lies in actually programming the synthesizer, rather than in playing the keyboard. . . . There are keyboard players who play piano and organ, and there are synthesizer players who are more like technicians.'' (David Ball, 1982) Believe expertise should not be important: ''I have . . . a Prophet and a CS-80 – but I haven't used them that much. . . . I'm real impatient when it comes to getting all that technical stuff down.'' (Seth Justman, 1979)	Minimized Expertise is not important: ''[Digital] synthesizers make life much easier. . . . A lot of people [now can] just get intrigued with the sounds and don't really bother too much with technical ability. . . . These days, somebody can go in without knowing anything, switch a button, record, and make millions.'' (Michael MacNeil, 1983) ''You can sit down with one of the current units and, without very much effort, get some wonderful-sounding things.'' (Jerry Goldsmith, 1985)	Resurfacing Believe expertise should be important: ''The idea of buying sounds on the open market just doesn't appeal to me that much. If I do my own programming, I know I'll come up with something that will have my own individuality stamped on it.'' (Thomas Dolby, 1988)	Foregrounded Believe expertise is important: ''I love gear, and programming. There's a buzz to it, like a real logical buzz. It's like reading a map and finding out where you're gonna go.'' (Tom Jenkinson, 2001)	Settled Expertise is important: ''Learn the basics. . . . Draw a block diagram of how the sound was created, just by listening to it. . . . [Understand] the different components of synthesis and how they work together.'' (David Rosenthal, 2008)

* Musicianship is an element of occupational expertise throughout.

New, superior acoustic emulations also were appealing to musicians. In a 1987 interview, Rebecca La Brecque lauded ''the DX7's ability to produce very acoustic life-like sounds.'' In addition, musicians celebrated how digital instruments eliminated the quirks associated with analog circuitry, such as tuning instability. Danny Elfman commented on his adoption of digital in a 1987 interview: ''All my analog stuff got thrown out one by one. . . . When I did my solo album, all the synth and bass sounds were analog, and it was a tuning nightmare. I never want to go through that again.'' Table 3 provides additional evidence of how digital instruments supported synthesists' occupational goal during this period of digital disruption.

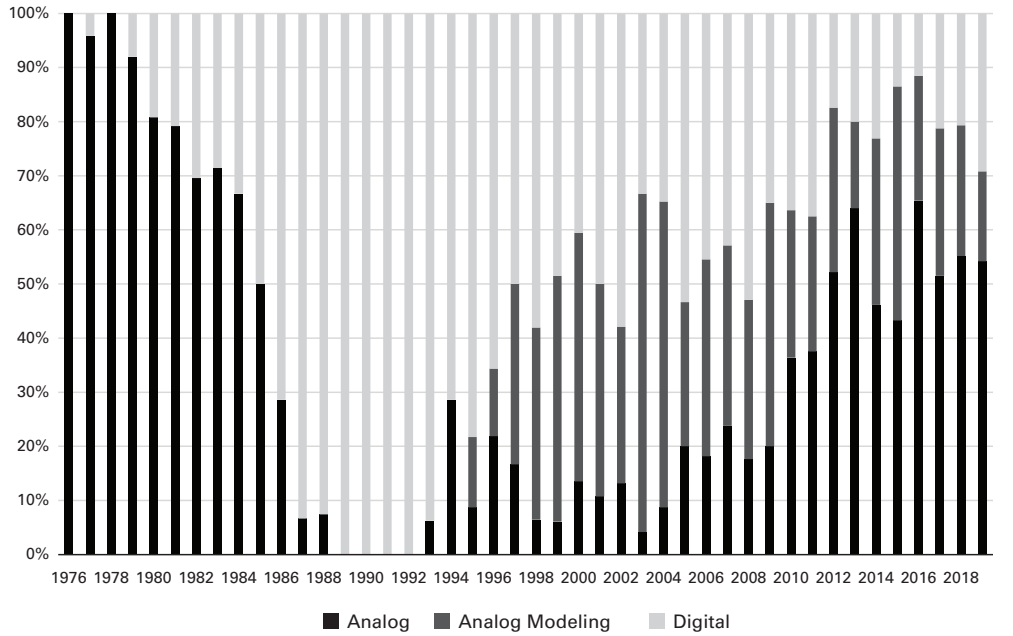
Occupational practices unsettled. As they did with analog synthesizers, musicians continued to play both synthy sounds and acoustic emulations, both of which digital synthesizers enabled. For example, Jonathan Cain of Journey said that digital synthesizers ''are really good . . . because they have such an incredible envelope. You can get just about anything out of them'' (1986). Dave Formula shared in a 1984 interview, ''I'm probably going to get the new Yamaha DX7. I tried it out in London, and I was very impressed . . . it's got a great string sound; they've really got the vibrato right.''

Occupational expertise: Technical expertise minimized. Due to their ease of use, digital instruments enabled synthesists to achieve their goal of distinctive creative expression without developing technical expertise. Thus, the introduction and early growth of these instruments was accompanied by reduced emphasis on technical expertise as important for the occupation. For example, musicians such as Michael MacNeil of Simple Minds commented, ''[Digital] synthesizers open up this whole new ground where you can really do the minimum and get good results'' (1983). Similarly, Jimmy Jam, who worked with both Janet Jackson and Prince, commented in a 1987 interview, ''When I look at a synthesizer, I go for the presets. If the presets aren't happening, I don't want it. I don't have much time to be fooling around. I just want to punch through some stuff, hit the sound, and say, 'Oh, yeah. This is it.' I mean, people get paid at the factory to put programs in it.'' Digital's ease of use also opened up synthesis to a new set of musicians. Jazz keyboardist Victor Feldman explained in a 1984 interview that he was attracted to new digital synthesizers when he had never used analog ones because ''The energy and the time needed for learning the programming aspects of [analog] synthesis would have taken me away from my musicality aspect.'' Table 4 provides additional evidence of the relationship between digital synthesizers and occupational practices and expertise during this period of digital disruption.

Digital Dominance (Mid-1980s to Early 1990s)

Producers engage in incremental digital innovation, and synthesists adopt digital widely. Through the mid-1980s and early 1990s, producers continued to introduce digital models, improving their acoustic emulations and expanding the number of preset sounds. For instance, a 1989 ad for the Kurzweil 250 explained that they had ''utilized [a] sophisticated mainframe computer to recreate acoustic sounds,'' which gave them the ''most accurate instrument sounds available anywhere,'' and a 1992 ad for Ensoniq boasted of ''an incredible library of over 1000 sounds . . . developed exclusively for ENSONIQ by some of the best in the business.'' In 1985, 50 percent of new models were digital. By 1989, every new model was digital, and almost no analog producers remained. Fueled by these new digital instruments, the synthesizer industry grew rapidly in the 1980s. Annual unit sales grew from 66,000 in 1983 (the year Yamaha introduced the DX7) to more than 350,000 in 1989—more than a five-fold increase (American Music Conference, 1990). Figure 3 shows data on the percentage of new models by technology over time, and Figure 4 shows the number of firms that produced analog, digital, and digital analog modeling synthesizers in a given year.

Figure 3. Percentage of Synthesizers Introduced in a Given Year that Are Analog, Digital, and Digital Analog Modeling



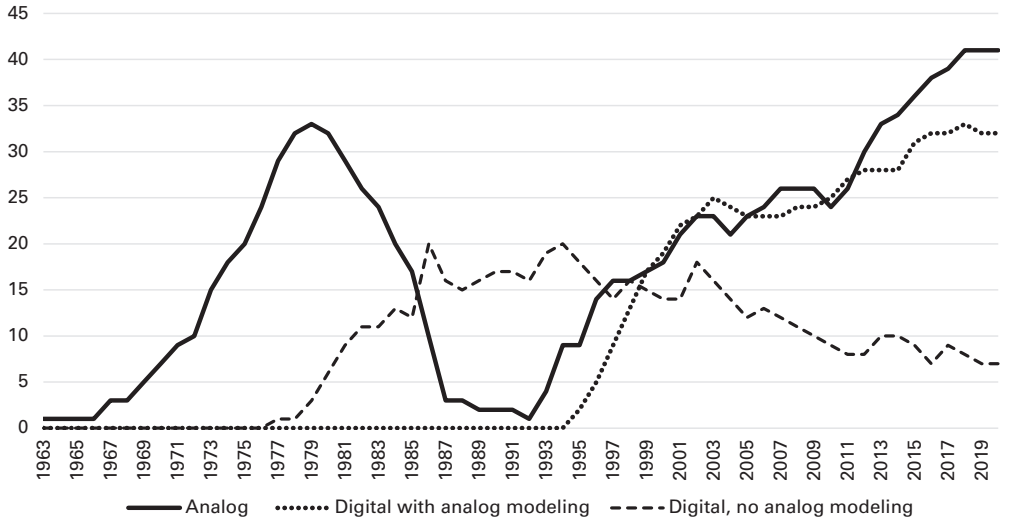
Saturation of digital synthesizers undermines occupational goal. Because digital synthesizers provided preset sounds, the rapid growth of digital synthesis meant that synthesists soon were all using the same sounds—in direct contradiction to their goal of distinctive creative expression. As early as 1985, Howard Jones lamented, ''I've gotten fed up with the DX7 bass sound . . . everyone is using it now.'' Similarly, in a 1987 interview, Philip Oakey of The Human League commented,

> I was getting really fed up with all those DX preset sounds. . . . They get really bland after a while. And when we get into what I call the DX Sound Hunt, it drives me up the wall. Someone in the studio will say, ''Okay! Let's have a bell sound.'' Then we start going through the 128 sounds on our DX. . . . If we find something we like, it has probably turned up on 50 records that have been made over the past few years. . . . Why couldn't we get our own sound?

As synthesists came to rely on widely used preset sounds, they struggled to achieve distinctive creative expression. See Table 3 for additional evidence of widespread digital synthesizer adoption undermining this occupational goal.

In addition, as digital synthesizers offered increasingly more-realistic imitations of acoustic instruments, they left little room for improvement. These preset acoustic imitations were programmed by producer-hired sound experts, and thus, even if synthesists *did* program their digital instruments, they were unlikely to create something better. As a result, musicians became limited in their ability to distinguish themselves on the basis of their acoustic imitations. In 1986, when an interviewer asked Nashville synthesist David Briggs if he tried

Figure 4. Count of Firms Producing Analog, Digital, and Digital Analog Modeling Synthesizers in a Given Year



programming the DX7, Briggs responded, ''I haven't had the need to. Most of the factory sounds that I use are great, and I haven't been able to improve on them. . . . Everybody wants the brass, electric piano, and string sounds.''

As a result of their undermined occupational goal, synthesists' critiques of digital use grew. These critiques resulted in occupational members narrowing their occupational practices and resurfacing the importance of technical expertise.

Narrowing occupational practices. Ironically, the significant improvement of digital technology's acoustic emulations made this very characteristic less appealing; musicians' inability to be distinctive with acoustic sounds led occupational members to focus on making music with synthetic instead of acoustic instrument sounds. Thus, while musicians often discussed creating acoustic sounds in the industry's emergent stage, their critiques of this use of the synthesizer grew in the mid-1980s—just as digital excelled in this role. For instance, Chick Corea opined in a 1985 interview, ''The synthesizer is not something that duplicates other things.'' In a 1990 interview, Trent Reznor of Nine Inch Nails complained, ''I'll go into stores and look around, but nothing seems exciting. . . . I don't need something to sound like a piano. I don't need a bass guitar replacement.''

In turn, many synthesists spoke of returning to synthetic sounds produced by analog instruments. For example, Jimmy Jam commented in 1990, ''For this album we've dug out the [analog] Omni, the [analog] OB-8. We've got the old [analog] Four-Voice hooked up. All the old things, because nothing gets those sounds.'' Similarly, David Bryan of Bon Jovi commented in a 1993 interview, ''Our new thing is, 'Old is good.' It's warmer. There's something about old gear. So we used a ton of it.'' As synthesists encountered digital saturation,

they shifted toward creating their own synthy sounds, especially those made by analog instruments.

Occupational expertise: Resurfacing belief in importance of technical expertise. Musicians linked these narrowed occupational practices around synthy sounds with a resurfaced belief in the importance of technical expertise. Rick Wakeman shared in a 1991 interview, ''Though we didn't know it at the time, that's [programming unique sounds] what made you identifiable. It's very difficult for keyboard players today to become identifiable, because people tend to buy instruments now for the [preset] sounds they've got.'' Similarly, when reflecting on what he would like to see in new synthesizers, Trent Reznor shared in a 1990 interview, ''I wish there was more emphasis on hard-core, 'let's-get-in-there-and-program' synths, rather than the 'it's-got-a-great-piano-patch' mentality.''

The undermining of their occupational goal, narrowed occupational practices, and a resurfaced belief in the importance of technical expertise led synthesists to express a desire for instruments that afforded control and embodied connection. Critically, these affordances differed from what digital's black-boxed presets and interface enabled.

Articulating desired affordances: Control. While digital's black boxing of sound creation was initially appealing to synthesists since digital preset sounds were novel and easy to use, this black boxing ultimately constrained synthesists' ability to be distinctive by crafting their own sounds. Unlike analog instruments, which provided access to each sound-generating component, digital instruments offered a limited set of parameters, and they buried access to these parameters behind small LCD displays and under layers of software menus. As synthesists focused on creating their own sounds and the desire to use their expertise, they expressed reservations about the lack of control afforded by digital instruments. For example, Alan Wilder of Depeche Mode recalled in a 1993 interview, ''The DX7 did initially impress me, because it had bell-like sounds that weren't readily available at that time. But you were f**ked if you wanted to change those sounds.'' Musicians also were frustrated by menu interfaces that did not afford easy manipulation of sounds while playing. Guy Fletcher of Dire Straits commented in a 1985 interview, ''[The DX7] really is an incredible little keyboard. But one thing that bothers me is that you have no control over your sound in real time.''

These frustrations led synthesists to clarify their desire for synthesizer technology that afforded them control to create their own distinctive synthy sounds, a characteristic they associated with analog. In a 1990 interview, Vince Clarke of Erasure explained, ''It [analog] gives you originality . . . because you're not working with preset sounds—tweaking them up and calling them your own. You've actually got to make the whole sound yourself with these analog synths.''

Articulating desired affordances: Embodied connection. Experience using black-boxed digital technology also caused synthesists to reevaluate the importance of embodied connection with their instruments. Analog

synthesizers had provided musicians with a tactile interface in the form of knobs. After interacting with digital's software menus, musicians expressed how they missed the physical connection provided by knobs, especially since they enabled real-time manipulation of sounds. For instance, Steve Lindsey commented in a 1990 interview, ''There's something about twisting a knob . . . I don't want to go into a computer program to take off some sustain.'' Bill Koepnick recalled in a 1990 interview why he missed his Minimoog from the 1970s: ''[On the Minimoog] there are no software pages, no 'hit this button six times to get to the LFO'—it's all right there in front of you. I'd really like to hammer on the hardware manufacturers to go back to knobs.'' Dave Stewart of Eurythmics likewise fumed in a 1992 interview, ''I have been synthesizing furiously since 1978 so have had plenty of opportunity to observe the development of instrument design over the last 13 years. Some trends have been pretty stupid—what bastard decided we didn't need knobs on our synths, and why wasn't I consulted?''

Such articulations prompted synthesists to express a preference for analog: a technology that afforded control and embodied connection. In fact, by the mid-1990s, some musicians began resurrecting their vintage analog gear—the only option available since new analog instruments were not being widely produced. For example, R&B artist Babyface listed his equipment in a 1990 interview: ''My favorites [all of them digital synths] would be the M1 and the D-50. I really do like this D-70 that's just come out. . . . I [also] use the Oberheim OB-Xa and the Roland JX-8P [both analog synths that had ceased production].'' When the interviewer then asked, ''What about the Minimoog? [another vintage analog synth],'' Babyface replied, ''Yeah, we use that too.'' See Table 5 for additional examples of synthesists' reflections on desired affordances.

Digital Imitation of Analog: Mid-1990s to 2000s

Producers introduce analog-like digital. Producers, of course, were aware of synthesists' concerns with digital synthesizers. In fact, in the 1990s a handful of startups perceived an opportunity to reintroduce analog synthesizers. The far more common response by established digital producers, however, was to emulate and incorporate analog features into digital instruments and to frame their digital instruments as analog-like. Thus, some producers emulated analog sounds with their digital synthesizers, even going so far as to make claims about producing ''real'' analog. For example, a 1993 ad for a Kurzweil digital synth claimed, ''If the job calls for a fat, analog bass sound, the K2000 delivers.'' A 1995 ad for the General Music S series claimed, ''The best thing we've got going for us is our great tone and that we've absolutely nailed the classic Moog, Arp, Prophet and Oberheim [analog] sounds.'' By the end of the 1990s, fully half of advertisements for *digital* instruments had an *analog* frame, highlighting analog characteristics (see Figure 5).

Other producers went further. In 1995, Clavia, a digital drum producer, introduced ''virtual analog'' technology. This digital technology, also called ''analog modeling,'' directly mimicked the behavior of analog circuits, attempting to provide more-faithful recreations of analog sounds. A 1995 ad for Clavia's Nord Lead featured the headline, ''1975 sounds. 1995 technology.'' The ad went on to claim, ''Enjoy punchy, fat analog sounds.'' As Figure 3 illustrates, the

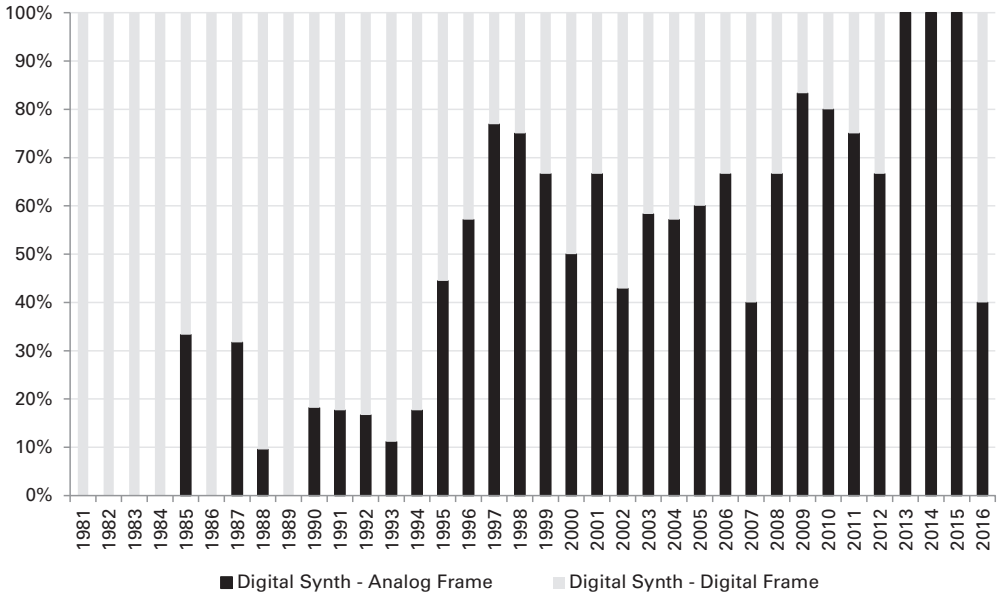
Table 5. Additional Evidence of Desired Affordances Across Phrases

Phase	Digital Dominance	Digital Imitation of Analog	Analog Reemergence
Control	''I've been moaning about this for years. . . . You want to simply go 'More attack, more release, change the tuning a little bit, knock off the chorus,' and play! On the equivalent analog machines of ten years ago you could do those things in less time than it takes to say them.'' (Rupert Hine, 1991)	''Preset synths can be dangerous. They can make you lazy. I'd rather sit and create a [sound] out of raw data than go into a box that has it pre-made.'' (Jonah Sharpe, 1998)	''The idea is to create your own world in your sounds. That's what I think it's all about.'' (Nick McCarthy, 2009)
Embodied connection	''This [analog] is more like taking a lump of clay and kneading it with your fingers on the knobs. . . . You can interact with the sound in complex ways.'' (Christopher Koenigsberg, 1992) ''Analog keyboards are really nice to work with. . . . Most of them have all the knobs on them and your mind flows instantly, because as soon as you think of twitching a parameter, all you have to do is turn it or push it or whatever. With digital, you'd have to go through pages of parameters, find the parameter, and then adjust it, which is more time-consuming.'' (Dwayne Dassing, 1996)	''[Digital synths] don't make me feel anything. . . . [But with analog], when I play a chord, it makes me feel like falling in love.'' (Judith Hamilton, 2009) ''I've always liked analog because it's hands-on and it makes the keyboard player look very active. When people see you twiddling knobs and putting patch cables in, and they immediately hear the result of your activity, I think it adds to the performance. . . . The activity of a keyboard player is as important as seeing a guitar player fling his arms around or play it with his teeth.'' (Keith Emerson, 2010) ''My analog stuff is the first thing I go to if I have time. I enjoy the tactile-ness of it, and the unpredictability. Most of the synths in my studio don't have any memory, so every time that I go to a [Roland] System 100M or a Moog modular or something like that, hopefully I'm going to be creating something completely different from what I did before.'' (Vince Clarke, 2012)	''Things have become so digital . . . everything is a touchscreen—that especially if you're a creative person, you like to feel a connection, an analog connection with what you're doing. So again, that speaks to the tactile hands-on experience.'' (2021 interview)

percentage of new models employing analog modeling—from many different producers—increased dramatically starting in 1995.

At the same time, and in response to synthesists' complaints, producers also incorporated knobs and sliders on digital synthesizers. For example, the Roland JD-800, the earliest digital instrument to take this approach, featured 60 knobs and sliders on its front panel. A 1991 ad for the JD-800 touted ''an array of intuitive controls that's mind boggling.'' Similarly, the Kawai K5000 had 16 knobs and two sliders to complement the usual digital display and pushbuttons. Ads from 1997 for the K5000 featured the word ''knobs'' in large font at the

Figure 5. Percentage of Digital Synthesizers Advertised in *Keyboard* Framed as Analog or Digital

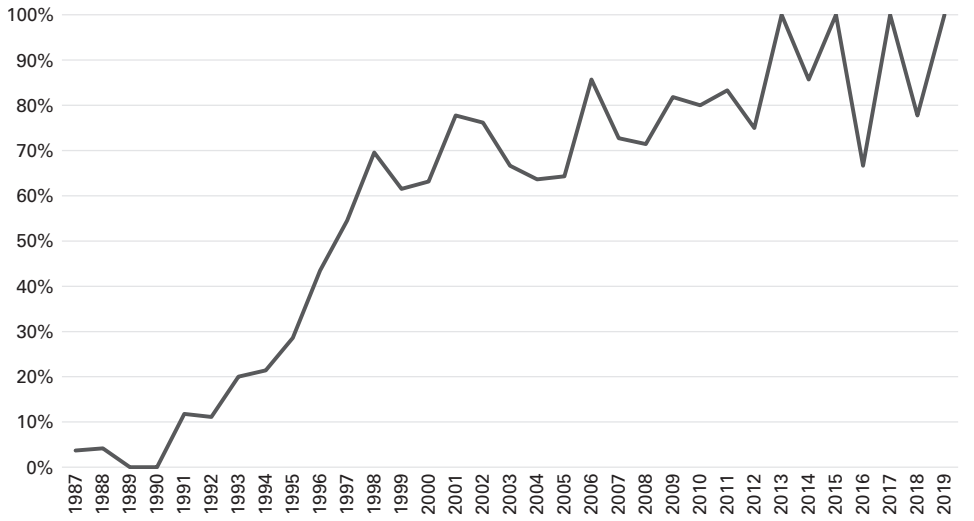


top of the page and included the text, ''twist a knob and hear a change.'' As Figure 6 shows, the percentage of digital synths with knobs increased from zero in 1990 to nearly 80 percent by 2001. Table A2 in the online appendix provides additional examples of producers framing digital synthesizers as analog-like.

Critically, however, digital knobs were not equivalent to analog ones. On analog synthesizers, each knob was tied to a given sound-generating parameter and directly adjusted this parameter. By contrast, digital knobs adjusted values in an algorithm but did not permit synthesists to directly program a sound from scratch or to alter the algorithm. As such, they did not move away from a preset orientation, nor did they facilitate the same analog ability to craft new sounds from scratch by accessing the core sound-generating technology. Thus, producers seemed to interpret synthesists' critiques as pertaining primarily to analog sounds and to the presence (or absence) of knobs, but as we detail below, synthesists tied both sounds and knobs to a deeper—and still evolving—occupational meaning and desired affordances.

Digital black boxing still undermines occupational goal. Although producers worked to make digital instruments seem more analog-like, they did so with preset analog sounds. Thus, their imitative efforts did not overcome the challenges that digital black boxing posed for distinctive creative expression. In interviews, synthesists still expressed a desire for unique sounds that enabled them to be distinctive, not the same analog sound as everyone else. Thus, as analog emulations spread, musicians felt the same frustration they had experienced with other digital presets and expressed a desire to move away from presets altogether. For instance, Brian Eno remarked in 1995, ''I

Figure 6. Percentage of Digital Models Introduced with Knobs



would like to see . . . a synthesizer that doesn't offer huge numbers of options in terms of stored sounds [presets] but does offer tremendous response to you as a player, so that you can actually start to feel what it's like to play this instrument.'' Similarly, deadmau5 commented in a 2010 interview, ''This is not to bash them at all, but if I hear another Massive [virtual analog] preset in an electro dance release, I'm going to shoot myself in the face.'' Continued interactions with imitative digital instruments therefore prompted occupational members to deepen their commitment to creating their own unique sounds, which meant using real analog instruments that made real analog sounds.

Narrowing occupational practices. As synthesists experienced digital imitations of analog, they clarified that they wanted a real analog sound with all its quirks and imperfections. Rick Wakeman shared in 2002, ''There's nothing else that can do what it [the analog Minimoog] does! . . . People have sampled them, and there are some good virtual synths floating around. But you can really tell the difference.'' Sting argued in 2004, ''Vintage keyboards . . . sound so much better. The whole experience of playing them is much more fun. The plug-ins [virtual analog] sound great, but when you hear them side-by-side, there's still no comparison.'' Perhaps the biggest difference between analog emulations and real analog stemmed from the fact that emulations were digital presets: a Moog sound on a digital synth was exactly the same every time it was invoked. In contrast, real Moog sounds were almost never the same due to the inherent variance in analog circuitry and to the fact that individual instruments differed. John Medeski commented in 1996,

> For me, all these digital synthesizers . . . may have a hundred or a thousand different sounds, but they don't have a thousand variations of each sound. They don't have a million variations, and for me personally, that's where the expression comes, to be able to get those nuances. . . . [With digital] you don't ever have your own tone. It made me realize that I need an instrument that I can have my own voice in, one that

> has enough subtlety and enough possibilities in tone color and sound and vibrational capacity that I can really express something on it.

Similarly, Warren Defever described a 1996 show in which multiple artists used the same model of analog synthesizer: ''We did a show where all the guys with Moog Prodigys stood next to each other and played. I set all my knobs exactly the same as the guy to the left of me, and a completely different sound came out. . . . That's the magic.''

While this unpredictability had been viewed as problematic in the early stages of synthesis, in an era of digital sameness, synthesists reinterpreted prior problems—such as quirks and tuning issues—as desired instrument characteristics that enabled the goal of distinctive creative expression. For example, Fancy commented in a 2003 interview, ''I love Moog Prodigies, because they do bad things. You don't even have to take them apart; they fall apart. They're totally unreliable, MIDI-incompatible, and don't stay in tune. . . . I love things that randomly impose limitations on you.''

Younger synthesists who were not active during the occupation's emergence period also turned to analog gear, and they expressed the same desire for analog quirkiness and unpredictability as other interviewees did. James Lavelle, who was only 13 years old when analog manufacturing initially ceased, explained in a 2005 interview, ''Suddenly you're putting a synth through this effect and something happens and 'woah!' We always have a rule: The moment we touch a keyboard, even if we're just f***ing around, we record it. A lot of things come out of that. . . . Half the time you'd never be able to recreate it. It's worth it.'' Thus, what was once a perceived shortcoming of analog instruments came to be seen as supporting occupational members' goal.

Occupational expertise: Foreground technical expertise. When digital became prevalent, synthesists had minimized the importance of technical expertise to the occupation's meaning. As synthesists emphasized the creation of their own analog sounds, however, they also reemphasized the importance of technical expertise. During a 2004 interview and in response to a question about what advice he would give to electronic music newbies, Jacob Thiele opined, ''It's good to learn analog synthesis. Just get a regular old analog synth—an old Roland Juno or something that has a nice sound to it, but doesn't have too many things you can screw around with, so you can figure out what the VCF does, what the VCA does, what the LFO does, what everything does, and how it all affects the character of the sound.'' The importance of technical expertise also emerged in musicians' emphasis on the technical aspects of sound creation, in interviews about their music. For example, in 1998, William Orbit provided a detailed explanation of how he created certain sounds:

> It's all done with the onboard VCO, and it's all done in a very analog way. Basically, you have two hands, so you've got ahold of two knobs, and you set it up for that golden spot. Every synth has that little G spot where subtle, slightly tweaking of two parameters takes you through a huge range of sound. . . . I think people who use lots of [analog modeling] plug-in programs don't always understand that it's better to start off using different VCOs. . . . The way an analog echo throws its repeat back, for

> example, and the timing of its repeat versus the way a computer does it. It might be subtle, but we can tell that.

Table 4 provides additional evidence of foregrounded technical expertise during the era of digital imitation of analog.

Clarifying desired affordances: Control. Synthesists' renewed emphasis on technical expertise reinforced their desire for synthesizers that afforded control through hands-on programming (i.e., analog) over those that black boxed the sound generation process. Thus, synthesists linked control both to expertise and to a desire to demonstrate mastery of something challenging. As Nick Rhodes of Duran Duran explained in 2011, ''There's something about an analog synth . . . there's something about the fact that they're wilder. You have to sort of get them under control, and fiddle with them manually to make them do what you want them to. Whereas with a digital sound, people just tend to keep clicking through them until they find something that works.'' Alessandro Cortini expressed a similar sentiment in 2009: ''Damned if it didn't take me two weeks to get that thing [analog synth] to make a sound. . . . I came close to returning it and asking for my money back. . . . That's where I got my first education on building sounds from the ground up . . . there was something about crafting new sounds that I found stimulating.''

Clarifying desired affordances: Embodied connection. Synthesists also clarified that they desired embodied connections that were not merely tactile but also contained a more material or even emotional valence. In fact, reflecting on their experience with digital and imitative instruments, many musicians stated that such instruments simply could not provide the same connection as a ''real'' instrument could. For example, Trent Reznor noted in a 2005 interview,

> I've really fallen in love with 'em [analog synths] since the last record. Plug-ins [digital emulations] have gotten very good. . . . Still, there's something about having a tangle of cables hanging there with real voltages coursing through 'em. VCA distortion—a ''what the hell's making it sound that way?'' factor.

Similarly, Tim Rice-Oxley commented in a 2005 interview, ''That sound [on an analog synth] made me want to write that solo; it's a result of that organic connection you get with a real instrument. . . . Just twiddle a few knobs and you've got an interesting sound. You can literally feel your way around a sound, which I think is really important.'' Table 5 provides additional evidence of how synthesists clarified their desired affordances.

Because analog-like digital synthesizers afforded neither the control nor the embodied connection that synthesists had come to prioritize, these shortcomings eventually fueled demand for real analog synthesizers among both veterans and newcomers.

Analog Reemergence (Early 2000s to Present)

Producers reintroduce early analog technology. Producers met this demand by reintroducing analog synthesizers to the market. As Figure 3 illustrates, the percentage of analog synthesizer introductions increased from zero in 1990 to roughly 50 percent in the most recent decade. Interestingly, these new analog synthesizers appeared to embrace the original analog offerings of the 1970s as an archetype, rather than 1980s analog synths that had attempted to incorporate digital-inspired features that enabled ease of use. For example, most analog instruments released in the 1980s introduced memory to store (user-created or preset) sounds, as analog struggled against the digital disruption. But fewer than half of analog instruments released in the 2000s had memory. Similarly, producers highlighted the analog quirks that synthesists had reinterpreted as desirable for distinctive creative expression. For example, in 2014 Analogue Solutions boasted, ''This synth has no memories . . . each parameter has that tiny analogue drift that adds so much to character. You are forced to be creative. No reliance on presets! Each time you make a sound you are being original.''

These claims were especially prevalent among producers that had offered analog in the 1970s and 1980s, had gone out of business, and were reincarnated with the original founders and new analog offerings in the 2000s. For example, Moog, which had gone bankrupt in 1986, reemerged and released a new analog model, the Moog Voyager, in 2002. Referring to founder Bob Moog, a 2003 ad for the Voyager read, ''Bob's back, making great new instruments under the name you love.'' The ad copy continued,

> The last of the original Minimoogs was made in 1981. Yet this classic remains a prized possession in studios throughout the world. Why? It's the sound. So fat, so smooth, so warm—it's like getting a huge sonic hug. . . . [The Voyager is] everything you loved about the original Minimoog—that fat analog sound, the wood cabinetry, the tilting front panel.

Another 2003 Voyager ad took direct aim at digital synthesizers: ''If you want that fat, rich, smooth analog sound, you're not going to get it pushing buttons on a digital sample player. You need the Voyager from Moog, the creator of the original Minimoog analog synthesizer. Its amazing sound is produced by all-analog circuits.''

Still other producers consisted of firms that had successfully transitioned from analog to digital. These firms also attempted to leverage their prior history in the industry. For example, in 2013 Korg released a reissue of its analog MS-20, which it had first introduced in 1978. They boasted that they employed the same engineers who developed the original MS-20 and that the re-released MS-20 would ''amaze you with its absolutely authentic analog synth sound.'' Similarly, in 2015 Roland introduced its first analog-based synth in 30 years. Figure 4 illustrates how the number of analog producers grew rapidly starting in the 1990s, while the number of producers that made only digital instruments declined.

At the same time, as Figure 3 illustrates, the industry has not experienced a wholesale return to analog. Instead, even as analog product introductions dominate the market, some synthesists also use digital synthesizers when they

enable distinctive creative expression. For example, in 2008 P-Thug of the synth-funk duo Chromeo explained that while he treasured the warmth of analog sounds, sometimes he still wanted to use digital: ''[T]here are two ingredients to our keyboard sounds: warm analog, and then that digital, crystal-like quality you heard in a lot of '80s stuff. There's nothing soothing or 'warm' about, oh, the DX7 harmonica, or that marimba patch they used on 'Axel F,' but sometimes that's what I want.'' Still, the dominance of analog and the use of both analog and digital to make synthy sounds, not acoustic imitations, are clear. In fact, every single reference to sound made by analog synth advertisements in the 1990s and 2000s is to original synthetic sounds, not to acoustic instruments.

It is also notable that the vast majority of contemporary digital instruments employ analog-inspired interfaces, feature analog-like sounds, and/or are advertised using analog-inspired language. Thus, digital itself has changed—moving from a technology built on differentiation from and improvement on analog to a technology built on similarity *to* analog. Ironically, while many observers had left analog synthesizers for dead in the late 1980s, 1970s analog technology has come to define the leading edge of the contemporary synthesizer market across both old and new technological generations.

Settled occupational meaning. The reintroduction of analog technology ultimately supported a settled occupational meaning, including the ongoing goal of distinctive creative expression, the practice of making unique synthy sounds, and the belief that technical expertise was a key element of the occupation. For example, one synthesist we interviewed in 2021 explained, ''I think that it really comes down to existential questions of people wanting to feel like they're doing something that's unique to them. And I think analog synthesizers . . . [let you] come the closest to whatever that might be or might make you feel that way, that you're able to truly carve out something that's unique or that you might even capture it that one time you'll never be able to capture it again.'' Another interviewee reinforced the idea that technical expertise and unique sounds tied to analog were intimately linked: ''It [my analog synthesizer] might take a little bit more playing around to get it where I want it to be. But ultimately, it may sound more interesting as a result.'' Table 4 provides further evidence of both settled practices and expertise.

Synthesists also linked this settled occupational meaning to the affordances of their instruments, specifically for synthesizers that afford both control and embodied connection. Echoing the theme of control, one synthesist we interviewed in 2021 noted, ''I like to turn this knob and hear an immediate effect. It's very different than doing so with a mouse.'' Another interviewee said, ''People tend to not like a lot of menu diving and screens and all kinds of, like, press shift and turn this. So, I think the more hands-on controls there are, I'm automatically more attracted to it, because I can see everything at my disposal.'' Other interviewees emphasized the importance of embodied connections, which provided both tactile and emotional connections. For example, a musician we interviewed in 2021 shared, ''For me, knowing that there are analog things happening under my hands, and not just ones and zeros shooting around, just feels more . . . I feel more connected to the instrument.'' Another interviewee commented, ''I have an emotional connection with

tangible things that I can get my hands on. And it makes me feel a certain way when I see my keyboard, and I'm able to play it.'' Thus, the technology trajectory and the occupation had come into alignment—and in the process, a once-displaced technology reemerged as dominant.

DISCUSSION

Our study explores why and how a previous generation of a technological tool can reemerge among professional users. Analyzing the case of the music synthesizer, we find that because of widespread adoption and use of digital instruments that black boxed key occupational practices and constrained the use of expertise, synthesists increasingly desired technology that afforded control and embodied connection. These affordances better enabled synthesists to accomplish their occupational goal and were consistent with evolving practices and perspectives on occupational expertise. In turn, emergent demand for these two affordances, which characterized old analog technology, was a key driver of reemergence.

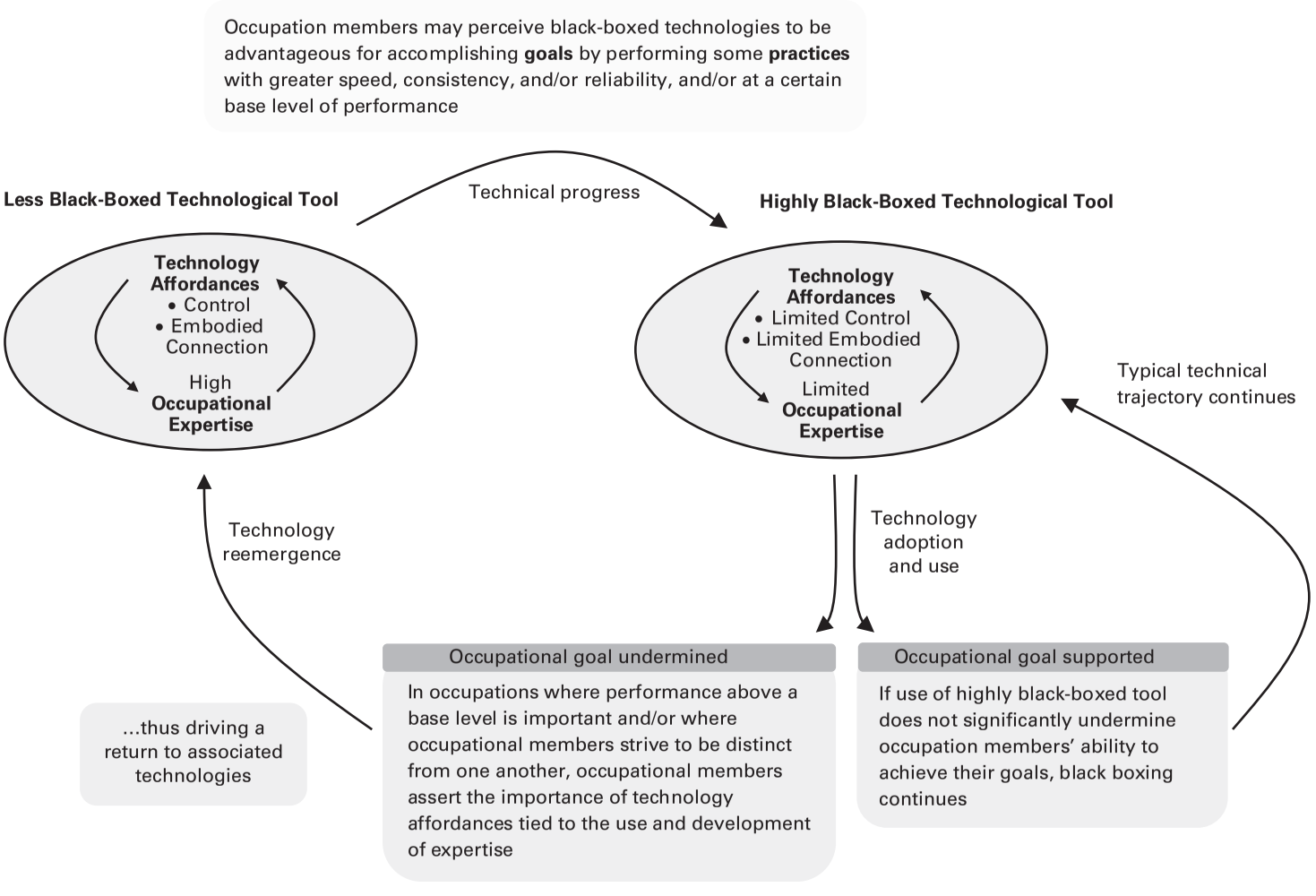
Our study makes three primary contributions. First, we integrate occupational considerations into the literature on technological trajectories by surfacing how black-boxed technology, typically viewed as an advance, may ultimately constrain occupational members' use of expertise to achieve key goals, leading to shifts in demand across technology generations. Second, we augment the technology life cycles literature by bringing an affordances perspective to the conversation, thus expanding on the conditions and processes that can underlie technology reemergence. Finally, we extend the literature on occupations and technology, illustrating how occupations may both shape and react to technological changes and how these interactions may shift over time with different consequences. We elaborate on each contribution below.

Occupational Influences on Technology Trajectories

A core contribution of our study is its integration of occupational dynamics and technology trajectories. Much of the literature on occupations and technology explores the impact of technology on occupations and social structures, unpacking how occupations respond to the introduction and use of a new technology (e.g., Barley, 1986; Zuboff, 1988; Orlikowski and Gash, 1994; Leonardi and Barley, 2010; Mazmanian, 2013; Nelson and Irwin, 2014; Bechky, 2020). By contrast, we examine the impact of occupations on technology, placing occupational considerations front and center in shaping technology trajectories. In this way, our study builds on prior work showing how users and their interpretations are an important influence on technology development (e.g., Pinch and Bijker, 1984; Garud and Rappa, 1994; Hargadon and Sutton, 1997), and our work investigates the role of occupational dynamics, specifically.

The black boxing of an occupation's technological tools is central to our account. Figure 7 illustrates a model of the relationship between occupations, the black boxing of technological tools, and technology trajectories. The left side of the figure depicts a less black-boxed technological tool, one that affords both control and embodied connection, which collectively support the development and use of occupational expertise. By contrast, a technological advance in the form of a more highly black-boxed technological tool, as depicted on the

Figure 7. Relationship Between Occupations, Black Boxing of Technological Tools, and Technology Trajectories



right side, may be perceived as advantageous for performing some occupational practices with greater speed, consistency, and/or reliability and/or for raising the base level of user performance. Indeed, automatic espresso machines and point-and-shoot cameras enable even amateurs to achieve results that better approximate what expert baristas and photographers might create. By definition, however, a more highly black-boxed tool affords more-limited control and a more-limited embodied connection.

Occupational users thus face a dilemma in their use of technological tools that black box key practices. On the one hand, because such tools may subsume knowledge and skill, black boxing can make it easier for occupational members, especially those with limited expertise, to perform occupational practices effectively. On the other hand, precisely because black boxing achieves these potential benefits by limiting control and embodied connection, the adoption of black-boxed tools can limit the development and use of expertise; in essence, it may cap experts' ability to achieve superior, or simply different, outcomes from others.

When black-boxed technological tools support occupational members' ability to achieve their occupational goals, then members will likely continue to embrace such tools, as the feedback loop on the right side of Figure 7 illustrates. For example, architects' adoption of computer-aided design (CAD) subsumed manual calculations and reshaped the use of drawing practices in building design. Yet, CAD also enhanced occupational members' ability to perform complex calculations more efficiently, which supported their design of buildings (Petroski, 1985). The adoption of subsequent generations of technological tools—including 3-D representations—followed a similar pattern of black boxing certain practices while facilitating the design of buildings with new advances (Boland, Lyytinen, and Yoo, 2007).

Our findings suggest, however, that limitations tied to black boxing can also challenge the achievement of occupational goals. In some occupations, members strive to differentiate themselves. This may be particularly true of occupations in cultural industries, including music and art. Because black-boxed technologies do not allow experts to fully access a technology's inner workings and to use their specialized expertise to differentiate themselves, occupational members in such settings may reject black-boxed technological tools and instead demand tools that afford control—even if that means a return to a previous technology generation. The feedback loop on the bottom left of Figure 7 illustrates this dynamic.

Relatedly, our findings suggest that when occupations emphasize expertise and demand performance above the base level that black-boxed technologies allow, occupational members will struggle with black boxing. In turn, their concerns may prompt adjustments to technologies and technology use. Frustration with black-boxed technologies thus generalizes beyond cultural industries. For instance, in automobile technology, a manual transmission affords drivers control and the ability to leverage their expertise in shifting to improve driving performance; the manual shifting of gears also affords embodied connection. Our findings predict that when these characteristics are important to occupational members (i.e., to professional drivers who strive to use expertise to distinguish themselves), they will select manual transmissions—and it is notable that NASCAR's top three levels of car racing still use manual transmissions. Similarly, in her ethnography of an accounting firm, Anderson

(2021) found that after years of using software tools that automated much of the planning and execution of audits, senior managers became concerned that junior auditors were not developing audit expertise. As a consequence, the firm reverted to more-manual methods that required junior accountants to use judgment. And Lebovitz, Lifshitz-Assaf, and Levina (2022) found that when radiologists could not unpack how their AI tools reached diagnostic conclusions, they overrode the algorithms and instead drew on their own expertise to interpret scans. Indeed, many new digital technologies tout ease of use and efficiency, which can ''lure'' users to adopt them (Bailey, Leonardi, and Barley, 2012: 1485). But our analysis demonstrates that if these technologies are easier to use because they black box key practices of occupational members and thus thwart the development and use of expertise that is important for accomplishing work, then such members may demand alternative technologies—including those that may strike outsiders as outdated.

While in our setting, the industry experienced reemergence of an older technological generation, our findings also have implications for the progress of technological trajectories more broadly. Specifically, in the development and implementation of new technologies, we would expect the degree of black boxing to be an important dimension (see also Anthony, Bechky, and Fayard, 2023). For instance, Apollo astronauts reportedly insisted on having the ability to override computer-aided systems and to retain full control over the spacecraft so that they could draw on their expertise to achieve their goal of safe, precise space flight (Hersch, 2012). More recently, when implementing an AI system to help police departments predict crime rates, the company ShotSpotter chose to use a machine-learning algorithm that was transparent, rather than a more opaque neural network, so that police officers could use their judgment to better identify potential bias (Davenport, Shankaranarayanan, and Stoddard, 2022). By contrast, opaque predictive AI-supported decision systems in the legal profession have met pushback from users citing concerns about legal expertise and professional liability. This pushback has led to design changes in these tools to make them more transparent (Kluttz and Mulligan, 2019). These examples highlight how concerns about black boxing that affects important occupational dimensions may also shape technological trajectories beyond reemergence.

These observations also reflect the importance of what Sennett (2008: 65) described as ''craft'' practices. These practices are often manual, focused on embodied skill and technique built through repetition, which connects workers to their work. According to Sennett (2008: 165), many craft-based occupations—from knife-making to medical diagnosis to financial services to engineering—have struggled against technological change, which has limited workers' participation in the process of work and can displace ''skilled handwork.'' Our findings extend Sennett's observations by demonstrating how such considerations can alter and not just reflect technology trajectories.

Our model thus suggests that what matters is not a technology transition per se, nor even the shift from analog to digital. Instead, the key is a technology's affordances, their relationship to occupational expertise, and the technology's relationship to an occupation's goals. We therefore reveal when and why occupational considerations may prompt shifts between different technologies, ultimately altering technology trajectories.

Future research could explore whether and how particular aspects of our setting were important to the patterns we observed. For instance, in our setting, occupational members had considerable agency over the adoption and use of technologies, and they enjoyed discretion over their work. Would reemergence be as likely in settings where occupational members are not the primary decision makers about their technological tools? In addition, synthesists operate outside of traditional organizational boundaries and work mostly in small interdisciplinary teams (i.e., bands). How might ongoing co-location with other occupational members and within organizational structures that shape interactions across occupational groups (e.g., Bechky and Chung, 2018) influence the relationships that members form with tools, and what might be the consequences for technology reemergence?

Technology Progression and Technology Reemergence

Dominant perspectives of technological evolution assert that technology continually marches forward. Thus, if demand for new technology in an industry is strong enough that it substitutes a prior technology, the old technology will not reappear (e.g., Utterback and Abernathy, 1975; Abernathy and Clark, 1985; Tushman and Anderson, 1986). By examining an exception to this pattern—reemergence of an old technology—we offer key boundary conditions to some of the existing literature's core assumptions and enhance our understanding of the relationship between technological change and industry evolution.

Specifically, to research on technological trajectories, our findings introduce the importance of affordances. Most research on technology life cycles has focused on comparing the relative performance of different technologies across dimensions of merit and features. For example, in evaluating the performance S-curves of disk-drive generations, researchers have measured attributes such as drive capacity, volume, weight, and access time (Christensen, 1992, 1993). While different segments might prioritize different attributes (Christensen and Bower, 1996), a key assumption of this literature is that a new technology that outperforms the old on relevant attributes is better. From this perspective, if an old technology has reached the limits of its S-curve and a new technology on a superior trajectory has taken over, we would not see the old technology reemerge.

By contrast, an affordances perspective emphasizes the interplay among the features, interpretation, and use of technology (Orlikowski and Scott, 2008; Leonardi, 2011; Faraj and Azad, 2012; Gibson et al., 2022). Thus, while producers can be prone to highlighting a technology's features, an affordances perspective emphasizes not features alone but, rather, users' interpretations of what a technology's materiality enables. In our setting, whether a technology enabled control and whether it enabled embodied connection emerged as important, valued affordances that ultimately influenced renewed demand for the legacy analog technology. Thus, users cared about not just the features of analog and digital synthesizers, like number of sounds and knobs, but how those features facilitated (or not) key desired affordances—does a knob enable the musician to control sound creation, and does it afford embodied connection?

Of course, the importance of affordances may vary across technologies and settings. In some cases, old and new technologies may not differ meaningfully

in their affordances of control and embodied connection. Computer monitors shifted from analog (CRT) to digital in the 2000s, but it is doubtful that CRT monitors provided more control or more embodied connection to users than do digital monitors, and thus CRT monitors are unlikely to reemerge. Moreover, when black-boxed technologies are a component in an integrated system and users do not interact with them directly, these technologies may not be problematic. For instance, Furr and Snow (2015) documented the transition from carburetors to electronic fuel injection (EFI) in automobiles, noting that EFI is superior for the primary metric that drivers valued, miles per gallon. Arguably, carburetors afford neither control nor embodied connection since drivers do not interact with them directly, and thus the transition to EFI was unproblematic even for professional drivers.

Industry setting also influences whether affordances will play an important role. Our study investigates an occupation within a cultural industry, a setting that may be particularly associated with occupational members' desire to strive for distinctiveness—especially since cultural industries can lack wholly objective performance standards. By contrast, in other occupational settings such as investment banking, engineering, or nursing, consistency and reliability may be valued over distinction, and comparisons between members may be less salient, even to these members themselves (e.g., Leblebici et al., 1991; Bailey and Barley, 2011; Anthony, 2021). In yet other settings, the ability to trust technologies without understanding how they work may not be a problem (Barley, Treem, and Kuhn, 2018). Thus, we should not expect the same affordances associated with a technology tool to be equally important in every setting, and by extension, affordances may play a lesser role in shaping technology trajectories in these settings, depending on the nature of how technology use enables or constrains workers' ability to achieve occupational goals.

These considerations also shine light on potential extensions of our investigation. The importance of distinction from other occupational members relates to research on fads and fashions (e.g., Hirsch, 1972; Abrahamson, 1991; Lieberson, 2000). This literature emphasizes that users may adopt technologies not (primarily) for technical performance reasons but, rather, because they imitate or diverge from other users' choices (Abrahamson, 1991). On the surface, the adoption and saturation of digital technology in our setting may appear like a fad or fashion-driven cycle: synthesists adopted digital because it was new and unique, but once everyone had the same digital sounds, they searched for something different. In a fads-and-fashions process, this search would lead adopters to chase the next fad until it, too, is saturated, and so on. In our case, however, the search prompted by digital saturation did not lead to a new fad but to the adoption of a less black-boxed tool that granted users greater control over their creations—and thereby the ability to accommodate multiple different tastes. Thus, while aspects of the dynamic appear similar to fads and fashions, the underlying mechanism differs.

At the same time, attraction to a technology's affordances need not be limited to occupational members and occupational tools. For example, the growing importance of embodied connection that we found among synthesists might apply more broadly to consumer industries in which such connections shape the experience of technology use. These connections might help to explain the comeback of vinyl records (Tantum, 2021), instant cameras (Metz and Wilson, 2021), and even board games (Sax, 2016).

Moreover, although the affordances of control and embodied connection were entwined in our setting, they differ conceptually. Control could exist without embodied physical connection, as in software products such as Stata, a statistical tool that allows users to modify assumptions or even program new modules. Similarly, the tactile interactions of embodied connection can exist without control, as in the consumer-oriented examples discussed above.

Finally, our work extends the limited research that has started to explore the drivers of technology reemergence. As noted above, Raffaelli's (2019) early study of this phenomenon found that the reemergence of mechanical Swiss watches occurred as Swiss watchmakers reframed the meaning of the watches from functional to elite, aesthetic artifacts that represent art. Our study outlines an alternative pathway to reemergence by illustrating that reemergence can occur without redefinition of the focal technology product: new analog synthesizers were used by the same market segment (professional musicians) to perform the same function (making music) that both digital and the original analog synthesizers enabled.

We also show that technology reemergence can be an emergent and user-driven process. In contrast to mechanical Swiss watches, the reemergence of analog synthesizers was not a purposeful process led by producers; instead, it was driven by a gradual resurgence in demand from occupational members. In fact, most producers resisted the reintroduction of analog and responded to early user feedback by making digital more like analog. A significant wave of real analog product introductions occurred only after musicians expressed dissatisfaction with digital imitations of analog and voiced their desire for real analog. Thus, our work highlights a demand-based view of technology evolution (e.g., Adner and Levinthal, 2001) and complements Raffaelli's framework by placing occupational members, not producers, as central in driving reemergence.

Technology and Occupational Change

By examining the interactions between occupational users and technology trajectories, our work also extends our understanding of how occupations themselves evolve. A large body of literature has examined how occupational members resist and respond to new technologies. For instance, prior work has focused on how new technologies may shape occupational identity (Nelson and Irwin, 2014), expertise and tasks (Orlikowski and Gash, 1994; Kellogg, Orlikowski, and Yates, 2006), and power and status structures (Morison, 1966; Edmondson, Bohmer, and Pisano, 2001; Anthony, 2018). Our work explores specifically the technology-influenced evolution of occupational meaning. Thus, we unpack how synthesists' understanding of their goal, practices, and expertise changed alongside different technologies in use. In our case, synthesists' overall goal of distinctive creative expression remained consistent over time, but the underlying practices, such as the types of sounds and the role of technical expertise, changed. (In other cases, goals themselves may change in response to new technology.)

Interestingly, whereas prior literature pointed to technological shifts as opportunities for occupational communities to expand their goals and practices and to move into other occupational jurisdictions (e.g., Abbott, 1988; Zetka, 2001), we instead find that synthesists *narrowed* their work by focusing on

increasingly specific synthy sounds, rather than competing for the jurisdiction of musicians who play acoustic instruments—even as digital instruments enabled synthesists to compete for these tasks more effectively than ever. This finding subtly but importantly expands our attention on technological change as an occasion not only to restructure role relations *between* occupations, on which prior literature has focused (e.g., Barley, 1986; Kahl, King, and Leigel, 2016; Pine and Mazmanian, 2017), but also to refine the meaning *within* an occupation. Specifically, we reveal that one's ability to stand out from other members of the same occupation may play an important part in shaping occupational meaning and its relationship to an occupation's tools, even at the cost of an expanded jurisdiction vis-à-vis other occupations. Prior literature on occupations has tended to focus on occupational members' commonality, the characteristics that bind them together (e.g., Van Maanen and Barley, 1984; Greenwood, Suddaby, and Hinings, 2002; Goodrick and Reay, 2010, 2011; Bechky, 2011, 2020). Yet, as synthesists' experience with easy-to-use digital technologies highlights, occupational members can struggle when technology limits their ability to draw on their unique expertise and to differentiate themselves.

At the same time, this refinement of the occupation's practices may represent a process of occupational closure: easy-to-use digital machines made the occupation's core practices widely accessible, even to those with limited expertise. Thus, the spread of digital was associated with lowering the bar to occupational membership, expanding the occupation and thereby making it both more imperative and more difficult to distinguish oneself. In turn, reasserting the importance of technical expertise and technological tools (analog synthesizers) that both support and require this expertise has raised the bar for occupational membership. Interestingly, synthesists accomplished this not via the common paths of certifications and professional bodies but, instead, through ongoing negotiation between their occupation's meaning and the technologies underlying their core tools (synthesizers).

These observations also suggest that the nature and structure of occupations may matter considerably to how occupational members interact with different technologies. Because our context is a creative industry, the occupational goal was to be distinctive (e.g., Faulkner, 2017). When goals are tied to creative outputs, threats to distinctiveness may become salient more quickly. Yet, observations from other occupations suggest that this phenomenon may exist beyond settings typically characterized as creative. For instance, surgeons (Beane, 2019), radiologists (Barley, 1990), and scientists (Lamb and Davidson, 2005) also compete with other occupational members for status and in their work performance by differentiating themselves. These findings thus suggest that future research must attend not only to occupational members' commonalities but also to their desire and ability to stand out as they collectively define an occupation's meaning.

Finally, our study reveals how the relationship between occupational members and their technological tools may unfold over long periods. Leonardi and Barley (2010) observed that most studies of this relationship focused on particular moments, such as the initial adoption of a new technology. Our study highlights how a complete understanding of this relationship may demand a much longer time frame than what scholars of occupations and technology have typically studied. The occupational members in our study did not initially

resist digital synthesizers but, rather, appeared to embrace this technology because they perceived it to support their occupational goal. Yet, by studying technology use over time and across multiple technological shifts, we found that occupational members later reinterpreted this same technology as undermining their occupational meaning—with dramatic consequences for the technology's trajectory. Our work thus encourages future studies of technology and occupations to adopt long perspectives on time.

Conclusion

Contemporary news headlines could lead one to believe that technology is an unstoppable force, marching ceaselessly forward as it requires occupational members to adjust or perish. Our study shows that this relationship is more complex—that occupations can both respond to *and shape* technology dynamics and that black-boxed technologies particularly may encounter pushback in some occupations. Yet, more work is needed to unpack how occupational and industry dynamics shape the reemergence of old technologies and technology trajectories more broadly. In a world in which the rate of technological change seems to be accelerating, appreciating the forces that shape the direction of technology development and adoption may be more important than ever.

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Supplementary Material

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REFERENCES

Abbott, A.
1988 The System of Professions: An Essay on the Division of Expert Labor. Chicago: University of Chicago Press.

Abernathy, W. J., and K. B. Clark
1985 ''Innovation: Mapping the winds of creative destruction.'' Research Policy, 14: 3–22.

Abrahamson, E.
1991 ''Managerial fads and fashions: The diffusion and rejection of innovations.'' Academy of Management Review, 16: 586–612.

Adner, R., and D. Levinthal
2001 ''Demand heterogeneity and technology evolution: Implications for product and process innovation.'' Management Science, 47: 611–628.

Adner, R., and D. C. Snow
2010 ''Old technology responses to new technology threats: Demand heterogeneity and technology retreats.'' Industrial and Corporate Change, 19: 1655–1675.

Alvesson, M.
2004 Knowledge Work and Knowledge-Intensive Firms. Oxford: Oxford University Press.

American Music Conference
1990 Music USA 90. Chicago: AMC.

Anderson, D. A.
2021 ''Legitimation, organization and change in professional work.'' Doctoral dissertation, Said Business School, Oxford University.

Anderson, P., and M. L. Tushman
1990 ''Technological discontinuities and dominant designs: A cyclical model of technological change.'' Administrative Science Quarterly, 35: 604–633.

Anteby, M., C. K. Chan, and J. DiBenigno
2016 ''Three lenses on occupations and professions in organizations: Becoming, doing, and relating.'' Academy of Management Annals, 10: 183–244.

Anthony, C.
2018 ''To question or accept? How status differences influence responses to new epistemic technologies in knowledge work.'' Academy of Management Review, 43: 661–679.

Anthony, C.
2021 ''When knowledge work and analytical technologies collide: The practices and consequences of black boxing algorithmic technologies.'' Administrative Science Quarterly, 66: 1173–1212.

Anthony, C., B. A. Bechky, and A.-L. Fayard
2023 '''Collaborating' with AI: Taking a system view to explore the future of work.'' Organization Science. DOI: 10.1287/orsc.2022.1651.

Anthony, C., A. J. Nelson, and M. Tripsas
2016 '''Who are you? . . . I really wanna know': Product meaning and competitive positioning in the nascent synthesizer industry.'' Strategy Science, 1: 163–183.

Askin, N., and M. Mauskapf
2017 ''What makes popular culture popular? Product features and optimal differentiation in music.'' American Sociological Review, 82: 910–944.

Bailey, D. E., and S. R. Barley
2011 ''Teaching-learning ecologies: Mapping the environment to structure through action.'' Organization Science, 22: 262–285.

Bailey, D. E., P. M. Leonardi, and S. R. Barley
2012 ''The lure of the virtual.'' Organization Science, 23: 1485–1504.

Bailey, D. E., P. M. Leonardi, and J. Chong
2010 ''Minding the gaps: Understanding technology interdependence and coordination in knowledge work.'' Organization Science, 21: 713–730.
Barley, S. R.
1986 ''Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments.'' Administrative Science Quarterly, 31: 78–108.
Barley, S. R.
1990 ''The alignment of technology and structure through roles and networks.'' Administrative Science Quarterly, 35: 61–103.
Barley, S. R., and B. A. Bechky
1994 ''In the backrooms of science: The work of technicians in science labs.'' Work and Occupations, 21: 85–126.
Barley, W. C., J. W. Treem, and T. Kuhn
2018 ''Valuing multiple trajectories of knowledge: A critical review and agenda for knowledge management research.'' Academy of Management Annals, 12: 278–317.
Basalla, G.
1988 The Evolution of Technology. Cambridge, MA: Cambridge University Press.
Beane, M.
2019 ''Shadow learning: Building robotic surgical skill when approved means fail.'' Administrative Science Quarterly, 64: 87–123.
Bechky, B. A.
2003 ''Sharing meaning across occupational communities: The transformation of understanding on a production floor.'' Organization Science, 14: 312–330.
Bechky, B. A.
2011 ''Making organizational theory work: Institutions, occupations, and negotiated orders.'' Organization Science, 22: 1157–1167.
Bechky, B. A.
2020 ''Evaluative spillovers from technological change: The effects of 'DNA envy' on occupational practices in forensic science.'' Administrative Science Quarterly, 65: 606–643.
Bechky, B. A., and D. E. Chung
2018 ''Latitude or latent control? How occupational embeddedness and control shape emergent coordination.'' Administrative Science Quarterly, 63: 607–636.
Benner, M. J.
2010 ''Securities analysts and incumbent response to radical technological change: Evidence from digital photography and internet telephony.'' Organization Science, 12: 42–62.
Benner, M. J., and M. Tripsas
2012 ''The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras.'' Strategic Management Journal, 33: 277–302.
Boland, R. J. Jr., K. Lyytinen, and Y. Yoo
2007 ''Wakes of innovation in project networks: The case of digital 3-D representations in architecture, engineering, and construction.'' Organization Science, 18(4): 631–647.
Christensen, C. M.
1992 ''Exploring the limits of the technology S-curve. Part I: component technologies.'' Production and Operations Management, 1: 334–357.
Christensen, C. M.
1993 ''The rigid disk drive industry: A history of commercial and technological turbulence.'' Business History Review, 67: 531–588.
Christensen, C. M., and J. L. Bower
1996 ''Customer power, strategic investment, and the failure of leading firms.'' Strategic Management Journal, 17: 197–218.

Clark, K. B.
1985 ''The interaction of design hierarchies and market concepts in technological evolution.'' Research Policy, 14: 235–251.
Cohen, S. L., and M. Tripsas
2018 ''Managing technological transitions by building bridges.'' Academy of Management Journal, 61: 2319–2342.
Colbeck, J.
1997 Keyfax Omnibus Edition. Milwaukee: Hal Leonard Corporation.
Cooper, A. C., and D. Schendel
1976 ''Strategic responses to technological threats.'' Business Horizons, 19: 61–69.
Davenport, T., G. Shankaranarayanan, and D. Stoddard
2022 ''ShotSpotter: AI and the future of law enforcement.'' The Babson Collection, case # BAB734.
DiBenigno, J.
2020 ''Rapid relationality: How peripheral experts build a foundation for influence with line managers.'' Administrative Science Quarterly, 65: 20–60.
Dosi, G.
1982 ''Technological paradigms and technological trajectories.'' Research Policy, 2: 147–162.
Edmondson, A. C., R. M. Bohmer, and G. P. Pisano
2001 ''Disrupted routines: Team learning and new technology implementation in hospitals.'' Administrative Science Quarterly, 46: 685–716.
Edmondson, A. C., and S. E. McManus
2007 ''Methodological fit in management field research.'' Academy of Management Review, 32: 1246–1264.
Eggers, J. P., and S. Kaplan
2009 ''Cognition and renewal: Comparing CEO and organizational effects on incumbent adaptation to technical change.'' Organization Science, 20: 461–477.
Eisenhardt, K. M.
1989 ''Building theories from case study research.'' Academy of Management Review, 14: 532–550.
Faraj, S., and B. Azad
2012 ''The materiality of technology: An affordance perspective.'' In P. M. Leonardi, B. Nardi, and J. Kallinikos (eds.), Materiality and Organizing: Social Interaction in a Technological World: 237–258. Oxford: Oxford University Press.
Faulkner, R. R.
2017 Hollywood Studio Musicians: Their Work and Careers in the Recording Industry. New York: Routledge.
Foster, R. N.
1986 Innovation: The Attacker's Advantage. New York: Summit Books.
Furr, N. R., and D. C. Snow
2015 ''Intergenerational hybrids: Spillbacks, spillforwards, and adapting to technology discontinuities.'' Organization Science, 26: 475–493.
Garud, R., and M. A. Rappa
1994 ''A socio-cognitive model of technology evolution: The case of cochlear implants.'' Organization Science, 5: 344–362.
Gibson, C. B., P. D. Dunlop, A. Majchrzak, and T. Chia
2022 ''Sustaining effectiveness in global teams: The coevolution of knowledge management activities and technology affordances.'' Organization Science, 33(3): 1018–1048.
Gilfillan, S. C.
1935 Inventing the Ship: A Study of the Inventions Made in Her History Between Floating Log and Rotorship. Chicago: Follett.

Goodrick, E., and T. Reay
2010 ''Florence Nightingale endures: Legitimizing a new professional role identity.'' Journal of Management Studies, 47: 55–84.
Goodrick, E., and T. Reay
2011 ''Constellations of institutional logics: Changes in the professional work of pharmacists.'' Work and Occupations, 38: 372–416.
Gopal, A., and P. Prasad
2000 ''Understanding GDSS in symbolic context: Shifting the focus from technology to interaction.'' MIS Quarterly, 24: 509–546.
Greenwood, R., R. Suddaby, and C. R. Hinings
2002 ''Theorizing change: The role of professional associations in the transformation of institutionalized fields.'' Academy of Management Journal, 45: 58–80.
Grodal, S., A. Gotsopoulos, and F. F. Suarez
2015 ''The coevolution of technologies and categories during industry emergence.'' Academy of Management Review, 40: 423–445.
Hargadon, A., and R. I. Sutton
1997 ''Technology brokering and innovation in a product development firm.'' Administrative Science Quarterly, 42: 716–749.
Hersch, M. H.
2012 Inventing the American Astronaut. New York: Palgrave Macmillan.
Hirsch, P. M.
1972 ''Processing fads and fashions: An organization set analysis of cultural industry systems.'' American Journal of Sociology, 77: 639–659.
Hutchby, I.
2001 ''Technologies, texts and affordances.'' Sociology, 35: 441–456.
Jenkins, M.
2020 Analog Synthesizers: Understanding, Performing, Buying, 2nd ed. New York: Routledge.
Kahl, S. J., and S. Grodal
2016 ''Discursive strategies and radical technological change: Multilevel discourse analysis of the early computer (1947–1958).'' Strategic Management Journal, 37: 149–166.
Kahl, S. J., B. G. King, and G. Liegel
2016 ''Occupational survival through field-level task integration: Systems men, production planners, and the computer, 1940s–1990s.'' Organization Science, 27: 1084–1107.
Kaplan, S., J. Milde, and R. S. Cowan
2017 ''Symbiont practices in boundary spanning: Bridging the cognitive and political divides in interdisciplinary research.'' Academy of Management Journal, 60: 1387–1414.
Kaplan, S., and M. Tripsas
2008 ''Thinking about technology: Applying a cognitive lens to technical change.'' Research Policy, 37: 790–805.
Keller, E. F.
1983 A Feeling for the Organism: The Life and Work of Barbara McClintock. New York: WH Freeman & Co.
Kellogg, K. C., W. J. Orlikowski, and J. Yates
2006 ''Life in the trading zone: Structuring coordination across boundaries in postbureaucratic organizations.'' Organization Science, 17: 22–44.
Kirsch, D., M. Moeen, and R. D. Wadhwani
2014 ''Historicism and industry emergence: Industry knowledge from pre-emergence to stylized fact.'' In M. Bucheli and R. D. Wadhwani (eds.), Organizations in Time: History, Theory, Methods: 217–240. New York: Oxford University Press.

Klepper, S.
1996 ''Entry, exit, growth, and innovation over the product life cycle.'' The American Economic Review, 86: 562–583.
Kluttz, D. N., and D. K. Mulligan
2019 ''Automated decision support technologies and the legal profession.'' Berkeley Technology Law Journal, 34: 853–889.
Knorr Cetina, K.
1999 Epistemic Cultures: How Scientists Make Knowledge. Cambridge, MA: Harvard University Press.
Lamb, R., and E. Davidson
2005 ''Information and communication technology challenges to scientific professional identity.'' The Information Society, 21: 1–24.
Leblebici, H., G. R. Salancik, A. Copay, and T. King
1991 ''Institutional change and the transformation of interorganizational fields: An organizational history of the U.S. radio broadcasting industry.'' Administrative Science Quarterly, 36(3): 333–363.
Lebovitz, S., H. Lifshitz-Assaf, and N. Levina
2022 ''To engage or not to engage with AI for critical judgments: How professionals deal with opacity when using AI for medical diagnosis.'' Organization Science, 33: 126–148.
Leonardi, P. M.
2011 ''When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies.'' MIS Quarterly, 35: 147–167.
Leonardi, P. M., and S. R. Barley
2010 ''What's under construction here? Social action, materiality, and power in constructivist studies of technology and organizing.'' Academy of Management Annals, 4: 1–51.
Leonardi, P. M., and E. Vaast
2017 ''Social media and their affordances for organizing: A review and agenda for research.'' Academy of Management Annals, 11: 150–188.
Lieberson, S.
2000 A Matter of Taste: How Names, Fashions, and Culture Change. New Haven, CT: Yale University Press.
Magaudda, P.
2011 ''When materiality 'bites back': Digital music consumption practices in the age of dematerialization.'' Journal of Consumer Culture, 11: 15–36.
Mazmanian, M.
2013 ''Avoiding the trap of constant connectivity: When congruent frames allow for heterogeneous practices.'' Academy of Management Journal, 56: 1225–1250.
Metz, A., and M. Wilson
2021 ''Polaroid Go is the world's smallest analogue instant camera.'' TechRadar, April 20. https://global.techradar.com/en-za/news/polaroid-go-is-the-worlds-smallest-analogue-instant-camera.
Morison, E.
1966 ''Gunfire at sea: A case study of innovation.'' In Men, Machines, and Modern Times: 17–44. Cambridge, MA: MIT Press.
Nelson, A. J.
2015 The Sound of Innovation: Stanford and the Computer Music Revolution. Cambridge, MA: MIT Press.
Nelson, A. J.
2017 '''Standing on [transparent] shoulders': Applying open source approaches to qualitative management research.'' In R. Mir and S. Jain (eds.), Routledge Companion to Qualitative Research in Organization Studies: 378–390. New York: Routledge.

Nelson, A. J., and J. Irwin
2014 "'Defining what we do—all over again': Occupational identity, technological change, and the librarian/internet-search relationship." Academy of Management Journal, 57: 892–928.
Orlikowski, W. J., and D. C. Gash
1994 "Technological frames: Making sense of information technology in organizations." ACM Transactions on Information Systems, 12: 174–207.
Orlikowski, W. J., and S. V. Scott
2008 "Sociomateriality: Challenging the separation of technology, work and organization." Academy of Management Annals, 2: 433–474.
Peterson, R. A., and D. G. Berger
1975 "Cycles in symbol production: The case of popular music." American Sociological Review, 40: 158–173.
Petroski, H.
1985 To Engineer Is Human: The Role of Failure in Successful Design. New York: St. Martin's Press.
Pinch, T. J., and W. E. Bijker
1984 "The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other." Social Studies of Science, 14(3): 399–441.
Pinch, T. J., and F. Trocco
2002 Analog Days: The Invention and Impact of the Moog Synthesizer. Cambridge, MA: Harvard University Press.
Pine, K. H., and M. Mazmanian
2017 "Artful and contorted coordinating: The ramifications of imposing formal logics of task jurisdiction on situated practice." Academy of Management Journal, 60: 720–742.
Pratt, M. G., D. A. Lepisto, and E. Dane
2019 "The hidden side of trust: Supporting and sustaining leaps of faith among firefighters." Administrative Science Quarterly, 64: 398–434.
Raffaelli, R.
2019 "Technology reemergence: Creating new value for old technologies in Swiss mechanical watchmaking, 1970–2008." Administrative Science Quarterly, 64: 576–618.
Reid, G.
2008 "Dave Smith Instruments Prophet 08." Sound On Sound, 24: 20–22.
Roland Corporation
2021 "Overview of consolidated financial results for the FY2020." Feb. 12. https://ir.roland.com/en/ir/library/result.html
Rosenbloom, R. S.
2000 "Leadership, capabilities, and technological change: The transformation of NCR in the electronic era." Strategic Management Journal, 21: 1083–1103.
Rosenkopf, L., and M. L. Tushman
1998 "The coevolution of community networks and technology: Lessons from the flight simulation industry." Industrial and Corporate Change, 7: 311–346.
Sahal, D.
1985 "Technological guideposts and innovation avenues." Research Policy, 14: 61–82.
Sarpong, D., S. Dong, and G. Appiah
2016 "'Vinyl never say die': The re-incarnation, adoption and diffusion of retro-technologies." Technological Forecasting and Social Change, 103: 109–118.
Sax, D.
2016 The Revenge of Analog: Real Things and Why They Matter. New York: Public Affairs.

Sennett, R.
2008 The Craftsman. New Haven, CT: Yale University Press.
Stummer, R.
2018 ''Back to the darkroom: Young fans reject digital to revive classic film camera.'' The Guardian, Jan. 27. https://www.theguardian.com/uk-news/2018/jan/28/does-reflex-slr-camera-herald-35mm-film-renaissance.
Styvén, M. E.
2010 ''The need to touch: Exploring the link between music involvement and tangibility preference.'' Journal of Business Research, 63: 1088–1094.
Suarez, F. F., and J. M. Utterback
1995 ''Dominant designs and the survival of firms.'' Strategic Management Journal, 16: 415–430.
Tantum, B.
2021 ''How vinyl has survived during the coronavirus pandemic.'' DJ Mag, March 30. https://djmag.com/longreads/how-vinyl-has-survived-during-coronavirus-pandemic.
Taylor, A.
2010 ''The next generation: Technology adoption and integration through internal competition in new product development.'' Organization Science, 21: 23–41.
Thomas, D.
1952 In Country Sleep, and Other Poems. New York: New Directions.
Tripsas, M.
1997 ''Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry.'' Strategic Management Journal, 18: 119–142.
Tripsas, M.
2008 ''Customer preference discontinuities: A trigger for radical technological change.'' Managerial and Decision Economics, 29: 79–97.
Tushman, M. L., and P. Anderson
1986 ''Technological discontinuities and organizational environments.'' Administrative Science Quarterly, 31: 439–465.
Utterback, J. M.
1994 Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change. Boston: Harvard Business School Press.
Utterback, J. M., and W. J. Abernathy
1975 ''A dynamic model of process and product innovation.'' Omega, 3: 639–656.
Vail, M.
2014 The Synthesizer: A Comprehensive Guide to Understanding, Programming, Playing, and Recording the Ultimate Electronic Music Instrument. Oxford: Oxford University Press.
Van Maanen, J., and S. R. Barley
1984 ''Occupational communities: Culture and control in organizations.'' In B. M. Staw and L. L. Cummings (eds.), Research in Organizational Behavior, 6: 287–365. Greenwich, CT: JAI Press.
Wadhwani, R. D.
2016 ''Entrepreneurship in historical context: Using history to develop theory and understand process.'' In F. Welter and W. B. Gartner (eds.), A Research Agenda for Entrepreneurship and Context: 65–78. Cheltenham, England: Edward Elgar Publishing.
Wadhwani, R. D., D. Kirsch, F. Welter, W. B. Gartner, and G. G Jones
2020 ''Context, time, and change: Historical approaches to entrepreneurship research.'' Strategic Entrepreneurship Journal, 14: 3–19.

Weick, K. E.
1993 ''The collapse of sensemaking in organizations: The Mann Gulch disaster.'' Administrative Science Quarterly, 38: 628–652.
Zetka, J. R.
2001 ''Occupational divisions of labor and their technology politics: The case of surgical scopes and gastrointestinal medicine.'' Social Forces, 79: 1495–1520.
Zuboff, S.
1988 In the Age of the Smart Machine: The Future of Work and Power. New York: Basic Books.

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