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RESEARCH ARTICLE

Modernism, modernity, and politics in the general history of science: Implications of Herbert Mehrtens' work, from "Vienna 1900" to the Nazi era, and beyond

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Argument
Herbert Mehrtens' work and the implications of the historical ideas he advanced went beyond the history of any single discipline. The article therefore addresses three broad issues: (1) Mehrtens' reconceptualization of mathematical modernism, in his field-changing book *Moderne—Sprache—Mathematik* (1990) and other works, as an epistemic and cultural phenomenon in a way that could potentially reach across and also beyond the sciences and also link scientific and cultural modernisms; (2) the extension of his work to the history of modernity itself via the concept of "technocratic modernism"; (3) his seminal contributions to the historiography of the sciences and technology during the National Socialist period, focusing on his critique of claims that mathematics, the natural sciences and technology were morally or politically "neutral" during or after the Nazi era, and on his counter-claim that mathematicians and other scientists had in fact mobilized themselves and their knowledge in support of Nazism's central political projects. Taken as a guide for understanding science-politics relations in general, Mehrtens' work was and remains a counterweight to the political abstinence adopted by many who have followed the "cultural turn" in history of science and technology. In the broadest sense, the article is a plea for the culturally relevant and politically engaged historiography of the sciences and humanities that Mehrtens himself pursued.

Keywords: Herbert Mehrtens; cultural and scientific modernism; symbol systems; technological modernity; Nazi-era science; science-politics relations

Introduction

The primary focus of Herbert Mehrtens' research lay in the history of mathematics, where his work has had considerable, indeed field-changing impact. However, Mehrtens' interests and the reach of his historical conceptualizations were not limited to the history of any single discipline, and some historians of science have tried to take his ideas even further than he did. In what follows, I propose to bring out and briefly elaborate some of these broader implications of Herbert Mehrtens' work, focusing in particular on three issues: (1) the potential of his work on modernism in mathematics for a general history of modernism in the sciences and for linking scientific with cultural modernisms; (2) the related potential of his work on the history of technical modernity and technocratic modernism; and (3) the implications of his seminal contributions to critical historiography of the sciences and technology during the Nazi era for a broader understanding of topics (1) and (2), as well as the political history of the sciences in general.

Although the three issues just named would seem to be disparate topics, and have often been treated separately from one another, I will suggest here that they are interrelated to a greater extent than has often been supposed, and that Mehrtens's work helped make it possible to conceptualize such interrelations. Specifically, I will note, first, as Mehrtens did, that modernism in the sciences has many faces, including but not limited to the liberation of self-referential symbol systems from the tyranny of representationalism in mathematics and theoretical physics. Second, again following Mehrtens and developing some of his contributions further, I will show in section (3) that although modernistic approaches in mathematics and physics were attacked in the Nazi era for ideological reasons, approaches based on technological or technocratic modernism were presented willingly by their advocates as resources for Nazism's central political projects. In the conclusion, I will briefly discuss more general implications of Mehrtens' concept of "self-mobilization" for a political history of science.

Some of the examples chosen to illuminate or elaborate the points made in this discussion come from my own work, for reasons that I hope to make clear in each case. The following study is thus presented both as a substantive contribution to the historiography of science and as a testimonial to a friend from whom I have learned much.

Part 1: The multiplicity of modernism and modernity[1]

Surely it is clear that, while modernism as a multifaceted cultural phonomenon is an important aspect of the history of modernity, the two histories cannot and should not be equated. Nonetheless, the two histories are intimately related, and both are also multiple, albeit in different respects.

The thesis of "multiple modernities," advanced by political theorist Shmuel Eisenstadt and also in different forms by postcolonial theorists, is surely well known to readers of this journal. Eisenstadt opposed the Euro-American focus of the modernization theory that had been dominant in the social sciences since the 1970s by refering to versions of modernization that had succeeded outside Europe or the United States, notably in Japan (Eisenstadt 2000). In contrast, the aim of postcolonial theorists was and remains to de-center Eurocentric views of modernity itself—to "provincialize Europe," as Dipesh Chakrabarty famously put it (Chakrabarty 2000; see also Gankar 2001). The fundamental contributions of both approaches to establishing the need for globalized perspectives on the history of knowledge, cultures and societies in the broadest sense are undeniable. However, talk of multiple modernities in that realm tends to reify both "Europe" or "the West" and "the East" as its "other," putting varieties of competing viewpoints into conceptual boxes in ways that do not reflect the actual plurality of modernities within the supposed Euro-American "center" (Culp 2020; on multiple "formations of modernity" see Hall 1997a).[2] Precisely this emphasis on plurality has also been characteristic of recent theoretical and cultural historical studies of modernism in European settings, to which I now turn.

Cultural modernism has long been considered to be the exclusive property of literary studies, art history, or the history of architecture. An important exception to this relatively narrow perspective is the inclusion of Freudian psychoanalysis in most accounts of modernism, especially those that focus on the remarkable outburst of creativity called "Vienna 1900" (Schorske 1980; Beller 2001; for challenges to Schorske, see below). While scholars have noted that the period around 1900 saw modernist initiatives in multiple fields other than those just named, including mathematics and the natural and medical sciences, little systematic work has been done to bring these into contact with modernism as it is conventionally studied. What, if anything, did these efforts to create and advance "modern" versions of mathematics, physics, biology or psychology have to do with one another, or with cultural modernism as it is commonly understood?

[1]Portions of this section have been reworked by permission from an earlier publication by the author (Ash 2018). Unless otherwise noted, all English translations from German texts are my own.

[2]Of course, one might also argue that "the West" reified itself in order to assert the superiority of a supposedly single version of "civilization" over all others. The classic statement of this view is Hall (1997b); a popularized reassertion of "Western" superiorty is Ferguson (2011).

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In a programmatic paper (Mehrtens 1984), and especially in his field-changing book, *Moderne—Sprache—Mathematik* (Mehrtens 1990), Herbert Mehrtens sought to reconceptualize modernism as an epistemic and cultural phenomenon in a way that could potentially encompass the full range of modernisms within and beyond the sciences, and perhaps even extend to a history of modernity itself. Focussing on the so-called "foundational crisis" in arithmetics and set theory, and following, in spirit, the introduction of non-Euclidian geometry in the mid-nineteenth century, Mehrtens characterized the modernist perspective represented by David Hilbert and others as the emancipation of symbol systems from the tyranny of representationalism.[3] In Hilbert's version, logical coherence—and not correspondence to anything in the actual world—became the primary, indeed the only truth criterion for mathematical theories. Hilbert's strong stand elicited considerable opposition, ranging from advocates of retaining some sort of empirical reference as a criterion of truth in mathematics to the intuitionism of L. E. J. Brouwer and others.

It is important to state clearly that Mehrtens did not posit a binary opposition between "modern" and "anti-modern" positions. As he wrote in a subsequent article, the opposition to Hilbert's position by intuitionists such as Brouwer or philosophers of mathematics such as Gottlob Frege is best described as counter-modern rather than anti-modern: "The counter-modernist attitude arises with modernism. It is part of modernity, of the modern world. That is why I chose the term counter-modernism instead of anti-modernism. It is the counterpart to modernism, insisting on the question whether there is not some natural substance to the truth and meaning of mathematics" (Mehrtens 1996a, 522). Thus, Mehrtens argued that both Hilbert's position and its intuitionist alternatives represented complementary aspects of the modernization of mathematical thinking during the foundational crisis of the 1920s.

I took up Mehrtens' conceptions in a paper published in German two decades ago, in which I attempted to show that the term "modern" carried rather different meanings in different scientific disciplines (Ash 2000). Whereas in physics, for example, the apellation "modern" generally signified theory-driven, mathematically expressed abstraction from the world of experiment, and was thus closely related to the parallel emphasis on the free play of abstraction central to modernist mathematics, the modernity claimed for Gestalt psychology lay in its founders' radical claim about the holistic character of conscious experience itself. Their emphasis on the claim that Gestalt phenomena were immediately experienced, not "built up" or constructed from punctiform sensations, appeared most particularly to place Gestalt theory in the vicinity of Brouwer's intuitionism. This perspective opposed the "impressionism" that was regarded as central to modernism in visual art and literature. At the same time, the Gestalt theorists strongly opposed anti-modern holisms and showed that the perception of immediately perceived wholes or structural relations and the relationships among them could be demonstrated by experiment. If we add to these approaches the propagation of "modern" biology as the replacement of traditional classifying morphology by experimentation on living organisms (Nyhart 2009), or the effort to establish a scientific philosophy on the basis of a philosophical analysis of language in the work of the Vienna circle and its allies (Stadler 2001), the variety of scientific modernisms becomes yet greater.

More recently, historians of science have broadened the debate still further and taken additional steps toward addressing the multiple linkages between the sciences, including medical science, and cultural modernism. These efforts have been particularly fruitful in the discussions of the phenomenon known as "Vienna 1900" (for more detailed discussion see Ash 2018). In her studies of medicine, culture and politics in nineteenth- and early twentieth-century Vienna, for example, Tatjana Buklijas (2012) shows how artists like Gustav Klimt took inspiration from nature and transformed natural motifs into abstract decorative forms. In one instance, the right corner of Klimt's famous painting *Danaë*, depicting the mythical moment when Zeus, in the shape of golden

[3]For more detailed discussion see the papers by Jeremy Gray (2023) and David Rowe (2023) in this issue. See also Siegmund-Schultze (2022).

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rain, surreptitiously impregnated the princess of Argos, is scattered with the shapes of a blastocyst. This early embryonic structure, first described in humans in 1895, was still a novelty at that time. Klimt may have learned of it by attending Emil Zuckerkandl's anatomical lectures for artists in the summer of 1903 (see the works cited in Buklijas 2012, 232). Here, innovations in medical science and in the arts appear to have gone hand in hand. Comparable interactions in modern architecture and psychiatry have been documented in the case of the mental asylum "Am Steinhof," founded in 1907 and designed in part by Otto Wagner, whose chapel building ornaments the ensemble to this day (Topp 2004; Blackshaw and Wieber 2012; Ledebur 2016).

Another well-researched example of science and Vienna modernism is the transformation of biology into an experimental science at the privately funded "Vivarium" laboratory (Hofer 2002; Logan 2013; Taschwer et al. 2016; Müller 2017). The work of "Vivarium" researcher Eugen Steinach on surgically induced sexual transformations in animals (Walch 2016), and of Paul Kammerer on the (supposed) inheritance of acquired characteristics in amphibians, attracted considerable media attention—much of it scandalous (Taschwer 2019). The central idea behind that work—the malleability of living things—meshed well with the culture of creation central to modernism.

In *Vienna in the Age of Uncertainty: Science, Liberalism and Private Life*, Deborah Coen challenges Carl Schorske's classical interpretation of fin-de-siècle Vienna directly (Coen 2007; for critical discussion of Coen's thesis, see Hofer and Stöltzner 2012).[4] Vienna modernism, in her view, was not only a descent into the irrational following the crisis of liberalism, as Schorkse claimed. Rather, the probabilistic worldview characteristic of modern physics in Austria was itself an expression of the liberal culture propagated and transmitted by several generations of a single family—the Exners. In characterising the work of Franz Serafin Exner, professor of physics and physical chemistry at the University of Vienna from 1891 to 1920, Coen does not cite Mehrtens, but draws in part upon work by historian and philosopher of science Michael Stöltzner on what he calls "Vienna indeterminism" (Stöltzner 1999, 2002). These and other studies show that natural scientists clearly deserve to be included—not only as a sideshow to—but rather as integral participants in "Vienna 1900".

In my own contribution to this discussion (Ash 2018) I presented two related theses. The first was that there are certain affinities, and in some cases actual linkages, between the breakthrough to modern ways of thinking in the natural sciences and mathematics and the radical changes in the arts which occurred at the same time. The second was that modernism, and hence cultural modernity, was nonetheless fundamentally plural in these fields, and not the "totalizing project" that postmodernist thinkers tendentiously claimed it to be in order to advance their own pluralizing position (for an earlier statement of the latter claim see Ash 1999a).

With regard to the first thesis, I suggested, generalizing again from Herbert Mehrtens' work in mathematics, that modernism as an intellectual style in many sciences, as in the arts, involved a break with supposedly pictorial representation of nature and a turn toward giving free play to abstraction and theoretical imagination, which I described as an *emancipation of self-referential symbol systems*. A well-known example of this particular version of modernism in theoretical physics and its comparability with modernism in mathematics was articulated by Ludwig Boltzmann.[5] Boltzmann consistently advocated the independent status of mathematical models in physics, asserting that their importance went far beyond the mere summation of measurement data. He acknowledged that the "need to save labor" was an important reason for their use, as Ernst Mach had contended in his essay on the "economical" nature of physical theory (Boltzmann 1905 [1892], 1).[6] But the real purpose of mathematical models, in his view, was "the need to make the results of calculation observable [*anschaulich*]" (Boltzmann 1905 [1892], 2). In using this term

[4]The following paragraph has been adapted from Ash 2018, 25–26, by permission. See note 1.

[5]The following paragraphs have been shortened and reworked from Ash 2018, 31–32 by permission; see footnote 1.

[6]Cf. Mach 1986 [1910]. On the transition to statistical reasoning in mechanics see Stöltzner (1999).

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(and, elsewhere in the same text, the related term "sensorization" [*Versinnlichung*]), Boltzmann clearly meant something quite different from Mach's "sense impressions." He meant to give priority to theory, not observation, and to argue that the former guided the latter, not the other way around.

For Boltzmann, the labor involved in creating mathematical models in physics was not the convenient summary of sense impressions, as Mach would have it, but the development of "mental images" (*Gedankenbilder*). Indeed, Boltzmann argued that broad collections of facts (*umfassende Tatsachengebiete*) could never be described directly, but could only be depicted by such *Gedankenbilder*—that is, by systems of mathematical equations (Boltzmann 1905 [1897], 142). Though he spoke of images, representation and *Versinnlichung*, Boltzmann plainly did not mean any analogy to photographic imagery (in contrast, see Mach 1910 [1897], discussed in Part 2 below). Rather, for him, theories are symbol systems that stand on their own and are testable only as wholes; they are images of nature only in a very abstract sense. Although Boltzmann emphasized, as Einstein later did, that such symbol systems are not entirely self-referential, but rather subject to experimental testing, his emphasis on the independence of mathematical theory and on abstract theoretical rather than photographic pictures of nature has come to be regarded as central to the modern standpoint in physics.

Modernism in the sciences has been articulated in multiple ways, not all of which can be linked so directly to Herbert Mehrtens' work as that of Boltzmann's theoretical physics. As suggested above, biological modernists' emphasis on the plasticity of behavior and the malleability of living systems may have more to do with the technological than with the formalistic strains of modernism. Nonetheless, it should be clear that the implications of Mehrtens' study of modernism in mathematics need not be limited to that discipline. This is even more true of Mehrtens' work after 1990, to which I now turn.

Part 2: Technological modernism and technocratic modernity

Alongside the style of modernistic thinking based on the emancipation of symbol systems from the demands of representationism and its countermodernistic pendant, there also existed multiple versions of what Mehrtens called "technocratic modernism." This intellectual style presupposed a concept of knowledge based on what can be done with nature and the human-built world as well as human behavior. It was exemplified most clearly in the case of eugenics as a form of biological politics (for eugenics in Vienna see Baader et al. 2007), and in the re-conceptualisation of social science that took society itself as an object that could and should be acted upon by science-based policy, later termed social engineering (Brückweh et al., 2012). Quite similar styles of thinking were also evident in the work of Jacques Loeb on the mechanics of photosynthesis (Pauly 1987), in the efforts to establish the malleability of living things in the "Vivarium" laboratory mentioned above, and in the re-conceptualisation of substances in human bodies (such as hormones, vitamins and enzymes) as effective causal agents (*Wirkstoffe*) that could be synthesised artificially in the laboratory (Stoff 2014).[7]

In a sense, technological modernity created the infrastructure that made cultural modernism possible. Cultural historians and historians of science have long noted that the common context for the breakthroughs to modern styles of thought in both the sciences and the arts at the turn of the century is the technological transformation of the lived world resulting from the so-called second industrial revolution (for recent discussions see Bud et al. 2018). Central to that transformation were, *inter alia*: the radical reorganization of urban infrastructure and planning, which began with the construction of Vienna's Ringstrasse and the straightening of the Danube (Békési 2021; see also Klemun 2021), and continued through Hausmann's Paris and many other

[7]Max Horkheimer and Theodor Adorno elaborated aspects of this conception of modernity under the rubric "instrumental reason" in *Dialectic of Enlightenment* (Horkheimer and Adorno 1969), cited by Mehrtens (1990).

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projects; the shift from gas to electric lighting, which ultimately overcame the difference between day and night (see among many others Schivelbusch 1995), and the invention of the horse-drawn, then electrical streetcar and the construction of urban transportation systems that collapsed the boundary between city and countryside (Oldenziel 2018). All of these developments marked the emergence of the city as an artificial universe of sound and light, seemingly emancipated from any direct dependence on nature and its rhythms—a nature that was itself being transformed by the encroachment of the city. Already here, in these transformations of the lived world, we can see how difficult it is to separate the emancipation of self-referential symbol systems from technological modernity. Indeed, it could be (and has been) said that the metropolis itself was beginning to become a set of large technical systems in the late nineteenth and early twentieth centuries (Hughes 1987). For an example of how this process played out over time, we can compare the diagrams for the first networks of dynamos, created to provide electric power to portions of a city, with those produced decades later for entire cites and regions (Hughes 1993, 3, 8–9, 10–13). A further step along this path is the interlinkage of electrical and transportation systems, for example in the London Underground and the New York City subway.

That the technological transformations that enabled the rise of modern urbanity also informed scientific research practices is well known (for a recent study of this process in Berlin see Wise 2018). First telegraphy and then telephony transformed scientific communication, eventually becoming topics for scientific and technical research themselves. Subsequently, the invention of the phonograph expanded the range of the sensory experience of sounds in ways comparable with the revolutionary impact of the telescope on astronomy, or the microscope in the biological disciplines (Kursell 2016).

A well-studied example of this technological dimension of scientific practice is Ernst Mach's work with Peter Salcher on photographs of projectile motion, first published in 1887 (Hoffmann 2001).[8] The avowed aim of this study, according to Mach, was to "make the process perceivable"—in this case to capture photographically the pressure waves caused by the movement of an object through air at high speed (Mach 1910 [1897], 357). Mach later defined the aim of the recording apparatus in general as the "thickening of immediate perception" (*Verdichtung der Anschauung*) (Hoffmann 1997, 45; see also Stiegler 1998). Thus, for Mach, the term "sense impressions" included extensions of ordinary sensation by means of technology; the apparent difference between how things appeared to the unaided senses and these technologically produced images was, in Mach's view, merely quantitative, despite the extraordinary difficulties he encountered when he attempted to create such images.

Herbert Mehrtens addressed these technological dimensions of modernity briefly in *Moderne—Sprache—Mathematik* (Mehrtens 1990, Chap. 7) and in a paper presented at the 1990 congress of German sociologists, the theme of which was "The Modernization of Modern Societies" (Mehrtens 1991). There he argued that "modernity in science unfolds in a new conjunction between formal symbolic constructions, that is mathematics in the widest sense, and the creation of physical structures and processes, that is technology in the widest sense" (Ibid., 605). One link between the programs of modernist mathematics and technological modernism was the fact that technical planning presupposed mastery of formal reasoning. Taken together, mathematial formalism and technological concepts constituted what Mehrtens termed "the domination ideal of modernity" (*Beherrschungsprogramm der Moderne*).

In keeping with the professorship in the history department of the Technical University in Braunschweig, with emphasis in history of science and technology, to which he was appointed in 1992, Mehrtens' subsequent publications focused increasingly on the technological and technocratic aspects of modernity. In a brief essay for an exhibition catalogue entitled "Technology and Industry under the Sign of the Modernities," for example, Mehrtens distinguished between three "modernities," the first of which began with the printing press and the second with the

[8]This paragraph has been reworked from Ash 2018, 30, by permission. See note 1.

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mechanization of industrial production (Mehrtens 2002a). The third modernity, which began in the late nineteenth century, is generally seen as a cultural phenomenon, as in "Vienna 1900." Mehrtens, however, asserted, anticipating the historical research just outlined, that "the third modernity grew with and out of the age of industry" (Ibid., 32), noting that cultural modernism, the science-based industries, the beginnings of assembly line production and so-called "scientific management" all emerged at roughly the same time.

For Mehrtens, in this new situation "to be more productive is no longer the result of inventing and employing new machinery, but becomes a question of human organisation, including that of the self, and of technical things, including their codes and accounting techniques (*Berechnungsverfahren*), in space and time" (Ibid.). Just as in sewing machines the individual parts are produced in a standardized manner and then assembled, so was human labor also to be standardized and reorganized. In the work of Frederick Winslow Taylor and his disciples Frank B. and Lillian Gilbreth, "the rationalizers generally rationalized themselves" (Ibid., 33). In the same paper, Mehrtens made the connection to cultural and scientific modernism by noting that, around 1900, rationality itself lost a central support: the belief in the recognizability of the world in real space and time. Seen in this context, "the rationality movement" in industry "can be interpreted as an attempt to bring the world under control again through calculation" (Ibid.).

From the late 1990s onward, Mehrtens elaborated his analysis of Taylorism in further detail. In a paper entitled "Labor and Time, Bodies and Clocks" (Mehrtens 2002b), for example, he cited the stopwatch employed by Taylor to measure and then to standardize units of manual labor as a literal embodiment of instrumental reason. He also emphasized, however, that Taylor combined multiple measurements to achieve his aim, and that it was the systematic combination of these measurements, as well as the organization of cooperation between the laborers whose performance was being measured and their managers, that justified Taylor's calling his program "scientific management," despite its lack of any theoretical foundation. Mehrtens further noted that Taylor's follower Gilbreth used a carefully designed series of photographic images that were similar to the motion photography of physiologist Etienne Jules Marey in Paris, who is known today as the founder of labor science in Europe, to provide visual as well as quantitative support in the search for efficient movements in laborers (Ibid., 131; see also Brain 2007).

What, if anything, do the multiple modernisms in the sciences and the cultural fields sketched in Part 1 above have to do with technocratic modernity? One answer, advanced at the beginning of this section, is that the technological transformations of the urban world made cultural modernity possible. Another, more substantive answer might take note of modern experimental biologists' emphasis on the mechanics of plant growth or the malleability of organic forms, mentioned earlier, as manifestations of an integration of technical and natural scientific thinking. Closer to, but not identical with Taylorism was the early behaviorists' proposal to redirect psychology from the classification of elementary and higher mental processes to the prediction and control of behavior based on animal models. Still more telling is the case of eugenics, the institutionalization of which began around 1900. Though the field was initially presented as a new science, eugenics was in fact a technocratic social policy program that could not yet apply basic knowledge of human genetics, which did not yet exist at the time, but enabled research in that field by claiming that it was necessary in order to carry out eugenical selection correctly (see, e.g., Schmuhl 2005).

The prominence of such technocratically oriented research programs refutes the long-held view that the cultural modernists formulated resistance to or fundamental critiques of technology-centered modernity. Such claims were (and still are) based on the naive, perhaps wishful assumption that modernism in the arts was inevitably politically progressive, while anti-modernism was linked with conservative or reactionary politics. As Detlev Peukert (1992) already argued in his study of the Weimar Republic, such simplistic dualisms projected the political struggles of the 1960s backward into the Weimar period and failed to capture the multivalent linkages of culture and politics that actually existed at that time. Subsequent research by Anne Harrington (1996) and myself (Ash 1991, 1995) on left- and right-wing constructions of holistic

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science in this period, and earlier work by Jeffrey Herf (1985) on what he termed the "reactionary modernism" advocated by philosophers of technology and thinkers like Oswald Spengler, have confirmed this multivalence in detail. More recent work on holism in Weimar-era biology does not explicitly address political issues, but abundantly confirms the multivalence of holistic thinking in this field (see, e.g., Brandt 2022). In contrast, Birgit Nemec (2020) shows that opposition between modernist and traditionally conservative strategies for visualising the human body in anatomy textbooks remained in place in "Red Vienna."

The varieties of modernism, as well as the politically multivalent constructions of holism in the sciences, provided a large, complex pool of concepts and practices, from which scientists selected as they positioned themselves in the Nazi era (for selective uses of Gestalt psychology in the Nazi period, see Ash 2016b). In contrast to such twistings and turnings, Joseph Goebbels had no problem with technological modernity. In a speech at the opening of the Berlin Auto Show on February 17, 1939, he proclaimed that "We have never opposed technology" but wish only to impart to it a "German spirit," discipline it and put it into service for the German *Volk* (cited in Herf 1985, 196). This brings me to the third section of this essay.

Part 3: "Irresponsible purity" and "self-mobilization": Implications of Mehrtens' critical work on the sciences in Nazi Germany

To scholars working on the history of science in Germany, Herbert Mehrtens is known as co-editor, with Stefan Richter, of a wide-ranging essay collection that pioneered German-speaking historians of science's investigations of mathematics, the natural sciences and technology in the Nazi period (Mehrtens and Richter 1980; Mehrtens 1980). In his work on Ludwig Bieberbach and so-called "German mathematics" (Mehrtens 1987), he showed, as other scholars had done for so-called "German physics," that oft-cited ideological attacks on modernistic mathematics and physics in the Nazi era were not ordered from above, but were in fact efforts by scientists who had long opposed these trends to defeat them by political means. Mehrtens' most provocative contribution to this critical scholarship was his paper "Irresponsible Purity," published in German in 1990 and in English in 1996 (Mehrtens 1996b [1990]). Here and elsewhere, Mehrtens effectively countered apologists' claims that scientists had retreated to their workbenches or studies and produced only non- or apolitical "basic" science in the Nazi era, and labeled active collaboration with the regime "pseudoscience." His counter-argument was that so-called "basic" theoretical work and applied mathematics of high quality were both needed and actually employed to support Nazism's central political projects, in particular weapons development in the German war effort (Mehrtens 1986, 1996c; cf. Epple 2002). Mehrtens thus posed fundamental challenges to exculpatory claims, originating in the immediate postwar period, that mathematics, or the natural sciences in general, could possibly have been morally or politically "neutral" during the Nazi era.[9]

In his keynote address to the 1992 conference of the German Society for History of Medicine, Science and Technology, which brought together then-current scholarship on the history of these fields during National Socialism, Mehrtens (1994) took this argument further and spoke of "Collaborative Relations" (*Kollaborationsverhältnisse*). As the talk's full title—in translation "natural and technical sciences in the National Socialist state and their historiography"—makes clear, the address was not limited to mathematics. Most significant for understanding the broader implications of this lecture are the sections that discuss "the collaboration of the elites" and what Mehrtens, following historian of technology Karl-Heinz Ludwig (1974), called the "self-mobilization" of scientists and engineers under Nazism.

As Mehrtens pointed out, after the largely silent acceptance of the Nazis' dismissal of scholars and scientists of so-called "non-Aryan" descent, which he called the "fundamental compromise,"

[9] Mark Walker (2023) and Reinhard Siegmund-Schultze (2023) discuss Mehrtens' contributions on these topics in more detail in their contributions to this issue.

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German academics collaborated quite actively with the National Socialist regime in multiple ways, especially after the Nazis themselves moved toward cautious collaboration with bourgeois elites after the "revolutionary" phase at the beginning of the regime. As a result of this policy shift, university faculties and disciplinary societies remained in place after they had been politically and "racially" purged, thus offering institutional avenues for collaboration (for confirmation of this claim see, *inter alia*, Hoffmann and Walker 2012). After the Four Year Plan shifted economic planning toward preparation for war in 1936, and again after the war began, new institutional structures were put in place and Nazi actors, such as Rudolph Menzel, head of the German Research council from 1938, and Carl Krauch of IG Farben, built their own research empires (Flachowsky 2008). To these should be added Hermann Göring, head of the Four Year Plan and also of the Luftwaffe. As a result of all this, Mehrtens argued, science and science policy took on a "more technicist direction" (Mehrtens 1994, 24).

That this shift did not occur without difficulties was shown in a recent PhD dissertation, by Robert Frühstückl (2018a), on applied mathamatics in Vienna during the Nazi era, which was inspired in part by Mehrtens' ideas. In the debate on "pure" versus "applied" mathematics that began around 1900, he writes, mathematicians at the University of Vienna positioned themselves clearly in favor of "pure" science, though one of them voiced regret that the decision to allow technical institutions to award doctoral degrees obviated the need to integrate technical mathematics into university departments (von Escherich 1905, cited in Frühstückl 2018a, 73). The appointment of applied mathematician and Nazi party member Hans Huber to succeed the number theorist Philipp Fürtwängler at the University of Vienna, following the annexation of Austria in 1938, changed the direction of the department (ibid., 131; see also Frühstückl 2018b). The 1941 appointment of Wolfgang Gröbner, a specialist in applied geometry, was apparently intended to continue this trend, but Gröbner was ordered to Braunschweig shortly thereafter to assist in the establishment of an "Air Force Institute for the application of higher mathematical methods to problems of flight technology" (Frühstückl 2018b, Section 5.2.1). There he encountered first-hand a dilemma that had been noted by others since the late 1930s: university-trained mathematicians working in applied settings were required to jettison the purely theoretical orientation they had learned and to focus on solving practical problems such as calculating flight paths for antiaircraft shells, using methods that they had not been trained to employ. This example suggests that integrating classical and technological modernisms was not an easy task.

With the term "self-mobilization," Mehrtens articulated the additional thesis that the collaboration of scientists, physicians and engineers with central political projects of the regime—the racial "purification" of the German *Volkskörper* and the conquest of "living space" in Europe—were generally not commanded from above, but rather were willingly offered by the scientists, physicians and engineers themselves. Their total engagement in rocket science or other projects, and even in ostensibly unpolitical projects unrelated to the war effort, such as the compilation of mathematical handbooks, suggests in his view that those involved "used their competence to the utmost" (Mehrtens 1994, 27; on the role of these efforts in Nazi plans to "reorder European science," see Siegmund-Schultze 1986).

Mehrtens' verdict was clear: "The often-used claim that science was 'misused,' with its resonance of sexual exploitation and the rape of innocent victims, is inappropriate." Rather the opposite was the case: "Throughout the system scientists pressed their political-technical usefulness, in their own narrow self-interest. This collaboration took place wherever experts were needed: anthropologists, geologists, aerodynamics experts, electrotechnologists statisticians and so on" (Mehrtens 1994, 24). Theoretical sciences were in a more difficult position due to the ideological attacks just mentioned, but physicists were quick to work on the possible implications of atomic fission for generating electric power or building weapons as soon as the discovery became known.

Most important for later work was Mehrtens' claim that "the willingness to compromise was two-sided; on the political side as well one was often ready to reduce political claims in favor of expert qualifications" for the task at hand (Ibid., 25). In a 1996 survey of mathematics before and

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during the Second World War, Mehrtens argued that to make such collaborations possible, scientists and mathematicians were prepared to revise previously accepted views of their own expert qualifications. As part of the effort to create a diploma curriculum in their discipline in the early 1940s, "the mathematicians created the figure of the industrial mathematician as a new objective for mathematical training," in order "to show that mathematics was a practical and useful subject" (Mehrtens 1996c, 104). Whether such collaborations were motivated by ideological agreement and political loyalty due to German nationalism, or perhaps by a common hostility to Bolshevism, or by opportunistic careerism, was for Mehrtens a secondary issue. Surely all of these motives, or some combination of them, were at work. An anecdote from the period suggests that participants in such collaborations during the Nazi era were well aware of the mutual instrumentalization at work: When radio propaganda urged the mobilization of science in 1939 with the slogan "science in the service of the war," scientists simply reversed the expression and spoke (in whispers) of "war in the service of science" (Harwood 1997, 141).

The term "self-mobilisation" itself, and the thesis behind it, have since been widely accepted and are now routinely employed in the literature. Among the many examples of the fruitfulness of this perspective are studies of aeronautical and aircraft research by Helmuth Trischler (1992, 1996) and Ulrich Albrecht (1996). Albrecht's study shows how far this nearly fanatical commitment could go, extending to suicide planes made of wood designed in the last two years of the war. Going beyond the elite, Helmut Maier (2007) shows how scientists and engineers in armaments-related fields collaborated with middle- and upper-level management of armaments firms and the military to dynamize armaments construction and testing. The process of "working towards the Führer," as many of those involved termed it, helped to enable the increasing productivity of the German armaments industry until near the end of the war. Further examples from Kaiser-Wilhelm institutes extend from the appropriation of botanical specimens from Soviet laboratories (Heim 2002), to the acquisition of the brains of murdered brain-damaged children (Schmuhl 2009), and to the 200 blood samples from Mengele's infamous clinic in Auschwitz, acquired in an effort to establish a science-based test for "race" (Trunk 2009). Self-motivated engagement outside the Kaiser-Wilhelm institutes included efforts to mobilize spatial research, cartography, and geography in support of population policy and ethnic resettlement in Nazi-occupied territories (Svatek 2016). Contemporary historians have cited this and related literature on the behavior of scientists under Nazism, while showing how principles of modern management or "social engineering," presented to the regime by experts on their own initiative, became central to the execution of Nazism's murderous program (Patel and Reichardt 2016). What, if anything, all of this implies about the "modernity" of the Nazi regime itself cannot be discussed here. Mehrtens does not appear to have addressed the decades-long debate on that question.

Conclusion

In conclusion, I return to the three issues raised in the introduction. I hope to have shown (1) that in his work on modern mathematics Herbert Mehrtens made fundamental contributions to the project of historicizing modernism in the sciences, the implications of which go beyond mathematics and have proven useful in linking scientific with cultural modernisms. I also hope to have shown (2) that Mehrtens developed a fruitful approach to historicizing technical modernism and technocratic modernity, and (3) that his work on mathematics and science during the Nazi era, in particular the deliberate shift to technological and technocratic modernity, has impacted research on the relations of the sciences and politics in that period.

In my opinion, Mehrtens' emphasis on self-motivated elite collaboration, or "self-mobilization," can be read as a guide for understanding science-politics relations in general, both in Germany during the Nazi era and also in other cases. This perspective implies a more symmetrical, interactive conception of science-politics relations than has been generally accepted until fairly recently. The claim that alliance-seeking "collaborations" were at work to make all this happen implies that such alliances might take place in democracies as well as dictatorships.

I elaborated such an interactionist perspective more broadly in a paper published in German twenty years ago, the title of which could be translated into English as "Science and Politics as Resources for One Another" (Ash 2002; see also Ash 2016a). In this approach scientists are treated not as victims of political interference, but rather as self-conscious elites who enter into various arrangements with policymakers or political authorities in order to gain support for their research, while also being perceived as supporting or being useful to the given regime. In this perspective both science and politics are moving targets: regime changes that lead to changes in what counts as politics can also lead to changes in what is regarded as science for ideological or practical reasons.

Moreover, in this approach the resource concept is not limited to finances or personnel. Since the 1980s, science studies has shown that the concept can include far more than money, personnel or raw materials.[10] Concepts, rhetorical slogans and even theories were already being treated then as "cognitive" (I would now say, discursive) resources. However, the list of potential resource types is still longer: in addition to financing and personnel, work spaces, institutional networks and collaborations, research practices and the apparatus that enables them, epistemic resources such as images, graphics, books, patents and designs, as well as the attribution of ideological meanings and significance to certain scientific approaches and methods can all function as resources in this framework. Mehrtens' "collaboration relations" fall under the heading of social relations as resources in such situations. What is or is not a resource in such interactions cannot be decided *a priori*, but is rather an empirical question.

Seen in this light, Mehrtens' approach can be useful for developing a broader and more complex understanding not only of modernism in mathematics and the sciences, but also of the relations of science and politics. All this has, or could have, particular resonance today, as a remedy for the apparent political abstinence of many in our discipline during the current "cultural turn."[11] In the broadest sense, this paper can and should be understood as a plea for a culturally relevant and politically engaged historiography of the sciences and humanities. That is surely what Herbert Mehrtens also sought to achieve.

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[10]In *Science in Action*, Latour refers to the mobilization of "allies" and "actants" as "resources" to strengthen scientific facts or technical innovations, and also to the "recruitment of resources" from outside the laboratory in support of technoscienctific research (Latour 1989, 90, 152, 172). On the expansion of the resource concept to raw materials, see the papers in the special issue on "Resources" in: *Berichte zur Wissenschaftsgeschichte* 37:1 (2014).

[11]Mehrtens (1990) has been celebrated as a forerunner of this "cultural turn," although he did not abandon the social historical and political perspectives with which he began. For his own, somewhat ironic view of this issue, see Mehrtens 2009.

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