“Dial Gauge versus Senses 1–0”: German Car Mechanics and the Introduction of New Diagnostic Equipment, 1950–1980

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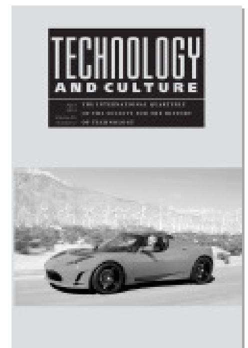

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SPECIAL ISSUE: SHIFTING GEARS

"Dial Gauge versus Senses 1–0"

German Car Mechanics and the Introduction of New Diagnostic Equipment, 1950–1980

STEFAN KREBS

For almost 120 years, the automobile as "sounding object" has been ubiquitous in Germany. Although at the time of the German Empire automobilism was still limited to a small group of upper-class motorists (*Herrenfahrer*), residents of urban and rural areas were already complaining vehemently about the diabolic "bang" of gasoline cars. With the rising level of motorization in the interwar period, car sound became—and has been ever since—the predominant noise source in urban areas. But the sounds of automobiles were more than just a nuisance: they developed into sonic icons for identifying particular brands and models, and as of the 1920s, a car's sound design evolved into an actively pursued feature of its overall design.[1] Moreover, car sounds soon became an important source of information for pedestrians and bicyclists in their navigation of urban traffic.

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1. The term "sounding objects" refers to R. Murray Schafer's distinction between "sound objects" and "sounding objects." For Schafer, the car was one of the sounding objects of our industrial modernity that turned the "hi-fi" soundscape of the preindustrial world into a "lo-fi" soundscape in "which signals are overcrowded, resulting in masking or lack of clarity." In contrast, sound objects should be designed to please the ear. See Schafer, *The Soundscape*, 272. See also Karin Bijsterveld and Stefan Krebs, "Listening to the Sounding Objects of the Past: The Case of the Car." For complaints about car noise during the German Empire and interwar period, see Uwe Fraunholz, *Motorphobia*; see also Karin Bijsterveld, *Mechanical Sound*, chap. 4. On traffic noise abatement in the postwar period, see Stefan Krebs, "Standardizing Car Sound—Integrating Europe?" For car sound design, see Karin Bijsterveld, Eefje Cleophas, Stefan Krebs, and Gijs Mom, *Sound and Safe*.

We have come to rely on this auditory sense of orientation to such an extent that today's silent electric vehicles are increasingly seen as a threat to traffic safety.[2]

The sounds produced by a car have also served as useful information on its technical state. Most drivers, for instance, have come to rely intuitively on their car's engine sound to decide when to shift up or down.[3] Or, while driving, they have learned to listen to the engine in order to detect some irregularity or improper functioning, a mode that can be described as "monitory listening." Finally, in the case of an actual problem, car mechanics rely on their ears to identify its nature. Since the early years of the trade this practice of "diagnostic listening" became an insignia of the profession[4] (fig. 1). And it stood metonymically for all embodied sensory skills car mechanics developed through training and experience. However, after the Second World War, the introduction of new diagnostic instruments contested sensory diagnosis and, in particular, the practice of diagnostic listening. This new discourse on car diagnosis negatively described the old practice, which relied on the mechanic's expert senses, as subjective and unreliable. Advocates of the new car diagnosis believed that objective and reproducible results could only be generated through testing equipment, and therefore they announced new diagnostic epistemologies and urged car mechanics to stop their old-fashioned practice. Their questioning of bodily repair knowledge not only contested diagnostic techniques, but also particular elements of the social practice of car repair, since sensory skills constructed and maintained the mechanics' professional identity, as well as hierarchies inside the repair shop. This is why German car mechanics, despite the propaganda for new diagnosis, did not embrace diagnostic technology until the 1980s and continued to deploy their sensory skills when diagnosing technical failures. This struggle between the traditional

2. The silence of (hybrid) electric vehicles is a threat to pedestrians and cyclists because people have grown used to relying on their ears in navigating urban traffic. A technical report from September 2009 concluded that hybrid cars have caused twice as many injuries among bicyclists and pedestrians than regular cars. See National Highway Traffic Safety Administration, *Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles*.

3. The manual gearbox has been the predominant technology in Europe since the 1930s; see Gijs Mom, "Translating Properties into Functions (and Vice Versa)." In this respect, Kurt Möser has distinguished four basic tasks of the driver: engine control, steering, taking part in traffic, and navigation; see Möser, *Fahren und Fliegen in Frieden und Krieg*.

4. These two modes of listening—aimed at noticing whether something is wrong and at revealing what in fact is wrong—differ in terms of objective and attention level. Accordingly, Karin Bijsterveld has proposed describing these two practices distinctively: "monitory listening" and "diagnostic listening." Bijsterveld, *Sonic Skills*. See also Trevor Pinch and Karin Bijsterveld, "New Keys to the World of Sound"; Stefan Krebs, "'Sobbing, Whining, Rumbling.'" For listening as an insignia of car mechanics, see also Krebs and Melissa Van Drie, "The Art of Stethoscope Use."

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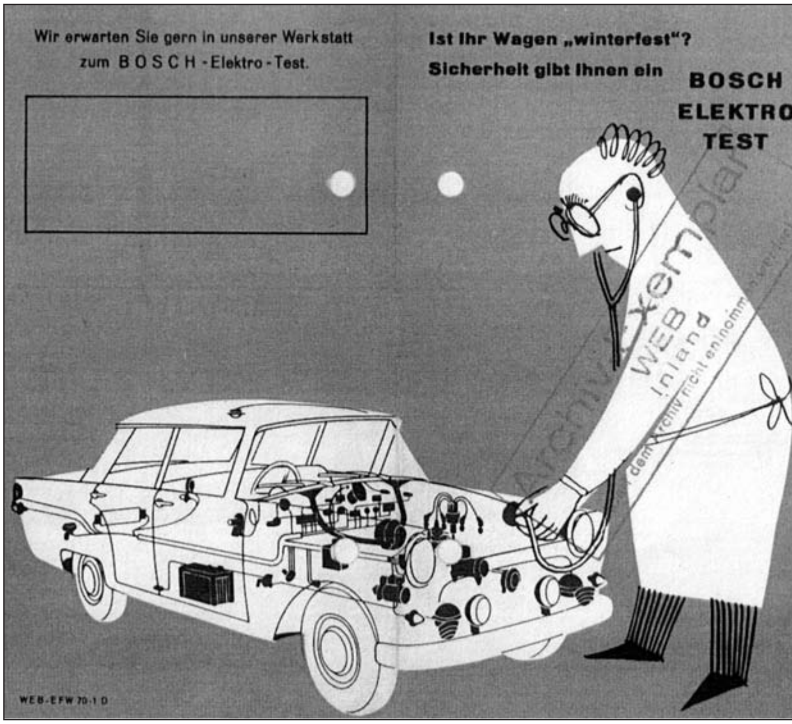

FIG. 1 1960s advertisement for the "Bosch Electro-Test." (Source: Robert Bosch GmbH, Historical Communication, Stuttgart, EF 005/005. Reprinted with permission.)

car repair regime and the new diagnostic epistemologies is the subject of this article.

The automobile has been one of the seminal objects of study in the history of technology. Most studies, however, have focused on the production, technology, or use of cars; comparatively little attention has been allotted to car repair.[5] Regarding the latter, Kevin Borg has even claimed that historians "have largely overlooked the whole automobile maintenance and repair industry."[6] Like Steven McIntyre, Borg has studied the history

5. For an intriguing account of the social construction of the automobile that highlights the dominant role of early motorists, see Kathleen Franz, *Tinkering*. David Edgerton has vividly argued that the history of maintenance, repair, and remodeling has received little attention in the history of technology. Edgerton, "From Innovation to Use." For his distinction between a history of technology-in-use and studies of users in the SCOT tradition, see Edgerton, "Innovation, Technology, or History," 688.

6. Kevin Borg, "The 'Chauffeur Problem' in the Early Auto Era," 797. Borg situates car repair in the "ambigious space between production and consumption," while Edgerton calls it a "twilight world, hardly visible in the formal accounts societies make of themselves." Borg, *Auto Mechanics*, 2–3; David Edgerton, *The Shock of the Old*, 83.

of the car mechanics trade in the United States. In their monographs and articles, both scholars concentrated in particular on the emergence of the trade until the Second World War. If Borg also included postwar developments, he largely focused on the difficult relationship between automobilists and car mechanics, one that he described as a permanent crisis of distrust, from the early days of chauffeur mechanics until the end of the twentieth century.

So far, the history of car mechanics in Europe has only been touched on, for instance in Gijs Mom and Ruud Filarski's history of Dutch mobility. My own work on German car mechanics has covered only the interwar period. In addition, several sociological studies have appeared that contribute to our understanding of the social practice of car repair. Douglas Harper has vividly observed and analyzed the work of a Saab mechanic in upstate New York, while Jojada Verrips and Birgit Meyer have written a beautiful account about car repair in Ghana. In addition, Julian Orr's work on maintenance practices of field mechanics for photocopy machines is insightful for understanding the bodily dimension and situated aspect of repair work.[7]

In her award-winning study on *Sensing Changes*, Joy Parr has encouraged historians of technology to look more closely at "embodied histories." She conceives of the human body as the highway to worldly knowledge: "We make meaning by doing and organize our awareness and skill through bodily practice."[8] Parr draws on Pierre Bourdieu's term of "embodied history." In *Pascalian Meditations*, Bourdieu describes bodily knowledge as the practical understanding of the world. In his view, the cognitive dispositions of an actor "are the product of incorporation of the structures of the world in which he acts; the instruments of construction that he uses to know the world are constructed by the world."[9] These dispositions are part of his notion of "habitus." To emphasize the bodily dimension of the habitus, Bourdieu introduces the term "hexis": "a way of bearing the body . . . a durable way of being of the durably modified body which is engendered

7. Stephen McIntyre, "'The Repairman Will Gyp You'"; Stephen McIntyre, "The Failure of Fordism"; Borg, *Auto Mechanics*; Borg, "'The Chauffeur Problem'"; Gijs Mom and Ruud Filarski, *Van transport naar mobiliteit*; see also Möser, *Fahren und Fliegen in Frieden und Krieg*, and Kurt Möser, "'Der Kampf des Automobilisten mit seiner Maschine.'" For Germany, see Stefan Krebs, "'Sobbing, Whining, Rumbling'" and "Notschrei eines Automobilisten"; see also Douglas Harper, *Working Knowledge*; Jojada Verrips and Birgit Meyer, "Kwaku's Car."

8. Joy Parr, *Sensing Changes*, 4. Historian Mark Smith is also an advocate of sensory history; see his "Producing Sense, Consuming Sense, Making Sense." See also the debate among David Howes, Sarah Pink, and Tim Ingold in *Social Anthropology* about doing sensory anthropology. For Howes, sensory perception is a cultural construct, whereas Ingold and Pink argue for a phenomenological understanding of our sensory perception. David Howes, *Sensual Relations*; Tom Ingold, *The Perception of the Environment*; Sarah Pink, *Doing Sensory Ethnography*.

9. Parr, *Sensing Changes*, 136.

and perpetuated, while constantly changing (within limits), in a twofold relationship, structured and structuring, to the environment."[10] The environment is the "field" an actor lives and acts in, and Bourdieu assumes a homologous relation between habitus and field. The habitus is structured through the logic, the rules, of the field and it is, at the same time, a "practical sense" that makes the actor feel at home in this field.

In this line of thinking, my argument here will reveal how the car mechanics' habitus, their bodily and cognitive dispositions, has been structured through the field of car repair, as well as how mechanics incorporated these dispositions and used them to make sense of the world of automobile repair. I will show that car mechanics in Germany between 1950 and 1980 used their expert senses to understand not only particular technical problems, but also the social world they inhabited.[11] The status of embodied skills was crucial for the professional identity of German car mechanics. Contesting the status of sensory diagnosis implicated the contestation of the car mechanics' sociotechnical position. My claim is that the unique system of German craft professions helped create robust sociotechnical hierarchies, which persisted throughout the contestation brought about by new diagnostic technologies. Habitus and craft pride centered around sensory and mechanical skills embodied during a long and painstaking apprenticeship. This embodied knowledge not only constructed hierarchies within the workshop—among apprentices, journeymen, and master craftsmen—but also successfully fostered the mechanics' expert status vis-à-vis customers. I will use a comparison of the German example with its American counterpart to show how sociotechnical hierarchies in the field of car maintenance and repair differed across time, place, and societal context—contributing to a history of technology-in-use.[12]

10. Ibid., 144.

11. Pierre Bourdieu, *Pascalian Meditations*, 128–63; see also Pierre Bourdieu, *The Logic of Practice* and *Outline of a Theory of Practice*.

12. See Edgerton's call for more "history of technology-in-use" in *Shock of the Old*, 83. This article draws on a close reading of car mechanics' handbooks and trade journals, sources from Robert Bosch GmbH, Historical Communication, Stuttgart (hereafter RB), and Company Archive Volkswagen AG, Wolfsburg (hereafter CAVW), and semi-structured oral history interviews. Between November 2011 and January 2012, I conducted six interviews (each lasting one to two hours) with former car mechanics who served their apprenticeship between 1937 and 1965. Although they worked in different settings (urban and rural workshops, as well as both small, independent workshops and big ones affiliated with a particular car manufacturer), these mechanics are not representative of the development of the profession between 1950 and 1980. However, the interviews were of great help to better understand the written sources. After a more biographical beginning, during which the interviewees told about the different steps of their professional careers, I took the opportunity to ask specific questions about particular sources to better situate them in the context of daily repair practices in the period under study.

The Senses and Automobile Diagnosis

In the mid-1950s the German car mechanics' trade journal *Krafthand* published a special series of leaflet inserts for apprentices and young mechanics.[13] In 1956 these leaflets, "Fachbriefe der Krafthand," were turned into an independent apprentices' journal, *Kraftfahrzeug-Kurier*. Two years later a second "journal for trainees in the car mechanics trade" was founded: *KFZ: Zeitschrift für den Nachwuchs des Kraftfahrzeug-Handwerks*.[14] These specialized publications were written to support the vocational training of future car mechanics. Aside from news about automotive technology and developments in the profession, the journals featured numerous contributions about the skills of the trade, such as the mechanical skills of filing, chiseling, and sawing, or skills pertaining to the handling of simple measuring instruments. Such "how-to" articles not only reveal much about the car mechanics' discourse on occupational skills and ways of learning them, they also highlight several problems of describing and transmitting such practical knowledge.

Two three-part miniseries, published in 1956 and 1965, are particularly relevant here because they explicitly discuss the question: how does one learn car diagnosis? Although mechanical skills and technological knowledge were described as preconditions for recognizing an engine's malfunctions, for a correct diagnosis, a mechanic had to use his senses. The first part of the 1956 series, "Learning to Observe," informed apprentices that right from the start of their three-year training program, they should pay careful attention and "keep their eyes, ears, and nose open" to learn automobile diagnosis: "[Those of you] who like their profession will soon notice that not just in the workshop but every time you see an automobile you will try—partly consciously, partly without even realizing—to draw conclusions from its performance. You will gradually cultivate the expert ear, the expert eye, and the expert nose."[15] The author of the 1965 series

13. The car mechanic's trade was a male-dominated domain in the period investigated. Only at gas stations were a few female pump attendants employed. Interview Immo Mikloweit.

14. My translation. I have also translated all of the sources cited in this article that were not available in English. *Krafthand*, first published in 1928 as *Die Reparatur-Werkstatt*, served as the official trade journal after the institutionalization of the independent car mechanics' trade in 1933. Until 1945 subscriptions were mandatory for all garages and repair shops. As of 1949, *Krafthand* was established as an independent trade journal. The *Fachbriefe der Krafthand* published from 1954 to 1956. The first journal created solely for apprentices was *Kraftfahrzeug-Kurier*, an offspring of *Krafthand*, published from 1956 to 1974. The second new journal, *KFZ: Zeitschrift für den Nachwuchs des Kraftfahrzeug-Handwerks*, was published between 1958 and 1999, after which it became a general car mechanics' journal.

15. "Lernt beobachten," 261. In the postwar period, the car mechanics' apprenticeship took three years in specialized workshops and three-and-a-half years in the automobile industry. "Kraftfahrzeugmechaniker—Kraftfahrzeugschlosser."

elaborated that everyone has five senses, but a young mechanic has to mold "these normal senses . . . into 'expert senses' during his apprenticeship."[16]

Let us first consider the expert eye. During the repair process a mechanic should inspect the state of the car, the engine, and every disassembled subsystem for visible signs of wear and tear. This "visual inspection" (*Sichtprüfung*) was one of the basic techniques an apprentice had to acquire. He gradually needed to develop the "intuitive gaze," which allowed him to notice every deviation from the "normal picture" right away, such as oil slicks or rust stains. In some cases, magnifying glasses might support the expert eye to check, for instance, the electrode of a spark plug. To learn the necessary visual skills mechanics could use exemplary illustrations in handbooks and journals that showed the typical appearance of overheated or sooty plugs. Mechanics should train their senses not only at work, however, but everywhere and all the time. Instinctively, for example, the mechanic's eye will scan all parked cars in a parking lot, whereby "the true expert eye will ignore the nine out of ten cars that are just fine and intuitively focus on the one car that is not."[17] It is possible for young mechanics to train their expert eyes on the streets each and every day simply by deciphering divergent visual signals, such as the bluish-white fume of an accelerating car. After all, merely "the color and density of exhaust fumes will tell experts a whole story."[18] Expert eyes should see at a glance if a car has technical troubles. To recognize them, the mechanic should react quickly and match his technological knowledge with the sensual input of his current observations. Another example given was a car with a suspicious-looking camber angle, which for some models could indicate a broken suspension spring.

Training the expert eye required experience and commitment: "You need to have the will to see *more* than others; with time you gain the necessary experience and then, one day, you will be one of the 'seeing.'"[19] Still, the expert eye was not only supposed to "see" technical problems, but also "read" the story of the overall appearance of a car and its driver: Did the owner carefully maintain his car or was it rather poorly maintained? Was the owner generous or tightfisted? A good mechanic had to take such visual information into account when considering a repair job. Here, the way of automobile diagnosis resembled the work of physicians, and indeed, car mechanics often compared themselves with medical vocations. The visual staging of mechanics as "car doctors" was common practice in automotive trade journals and handbooks since the interwar years[20] (see fig. 1).

16. "Kontrolle und Diagnose (Teil I)," 203.
17. "Lernt beobachten," 262.
18. "Kontrolle und Diagnose (2. Teil)," 266.
19. "Kontrolle und Diagnose (Teil I)," 204 (emphasis in original).
20. Julian Orr has described how service technicians should also consider whether a customer "knows how to talk about the machine." Orr, *Talking about Machines*, 83.

Although smell and taste could be considered the least helpful senses in automobile diagnosis, the tang of gasoline or odor of burned cables were important signals of danger which a young mechanic should learn to identify. The sense of taste could, at least in theory, be used to distinguish between water, battery acid, and gasoline, or to notice the subtle nuances of engine, transmission, and differential oil. Still, most liquids in cars posed serious health hazards and mechanics were asked to refrain from tasting them.[21] Of a different nature, the sense of touch was seen as of utmost importance for the actual repair process. Disassembling and reassembling engine parts without touching them was unthinkable, of course; nearly all nuts and screws were tightened by hand. Most mechanics would know how it feels to over-tighten a little screw, a feeling described by Douglas Harper as involving "detailed knowledge of materials." And sometimes mechanics also used their fingertips to sense invisible score marks on a shaft or cylinder wall. Overall, however, the sense of touch was not seen as crucial in automobile diagnosis.[22]

In contrast, the expert ear was presented as the key diagnostic proficiency. One author explained that "[t]he expert ear is probably even more important than the expert eye. Listening to recognize the actual problem, listening in, with a listening rod or just a screwdriver, to locate it—that is real diagnostic practice."[23] Everyday people listened to cars on the streets, kids easily learned to distinguish the characteristic sounds of different makes, and automobilists were told to listen to their cars while driving to notice audible malfunctions in time. However, to become skilled at the practice of "diagnostic listening," that is, to be able to hear what was wrong, was far more difficult: "[t]he real art of 'listening' to automobiles only starts where one complex sound dissolves into many single sounds and the mechanic's ear will be able to connect a particular source of noise with each one of them."[24]

As mentioned in the introduction, learning the sonic skill of diagnostic listening distinguished a mechanic from ordinary motorists. In order to acquire this ability he had to train his ears, just like his eyes, both within and outside of the workshop. A good mechanic, for instance, was able to

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Car mechanics considered the experience of their customers, too. Krebs, "'Sobbing, Whining, Rumbling.'" For the theme of the "auto-doctor," see Krebs and Van Drie, "The Art of Stethoscope Use"; some interviewees also made references to medical doctors, in particular when speaking about the stethoscope: interview Immo Mikloweit; interview Franz-Josef Hansen; interview Leo Franzen.

21. Interview Manfred Neuner. Another interviewee mentioned the sweet taste of antifreeze: interview Franz-Josef Hansen. See also "Kontrolle und Diagnose (Teil III)."

22. Harper, *Working Knowledge,* 118 and 124; "Zu Ende denken [B]," 76. See also Robert Pirsig, *Zen and the Art of Motorcycle Maintenance*, 323; Eugene Ferguson, *Engineering and the Mind's Eye*, 3–4; Shoshana Zuboff, *In the Age of the Smart Machine*, 36.

23. "Lernt beobachten," 263.

24. "Kontrolle und Diagnose (Teil II)."

routinely recognize an engine's troublesome "prr—prr—prr," compared to a continuous, healthy "prrrrrr," as an audible sign of a problem with one cylinder. To come to this conclusion, the mechanic should map his auditory observation, as in visual inspection, and bring it into line with his technological knowledge. He needed to ask himself how different subsystems interact, and how one malfunction could affect neighboring parts. To circumscribe audible problems, he could then test whether a noise stops after separating a particular subsystem from the engine or drive train, or whether the noise changes in pitch when gearing up or down. Another crucial strategy to locate a source of noise was to analyze the sound's rhythm: is it audible with every, or every second, revolution? If the latter, the fuel pump could be broken. In all these cases, the mechanic could rely on his ear's outstanding ability to examine the periodicity of sound.[25]

To further locate a source of noise, mechanics were advised to carefully listen to the suspicious part of the car. Thereby they could shield their ear with their hands to muffle surrounding sounds and focus on the suspicious noise. In some cases mechanics could also use listening tools. The simplest were screwdrivers and self-made listening rods, while the more sophisticated ones resembled medical stethoscopes. These stethoscopes could be equipped with different probes in order to listen to either large or very tiny spots. Still, the use of stethoscopes was hardly self-evident. Moreover, mechanics had to acquire the sonic skills to position the probe correctly, to put the earpieces on properly, and to adopt the right bodily posture.[26] The mechanics' use of rods and stethoscopes can be described as what Jonathan Sterne has called "audile technique": an embodied practice to isolate listening from other sensory input in order to focus and intensify the listening activity.[27] However, listening tools were only used for special purposes, such as the examination of the engine block or single bearings. The only instrument with an auditory display was a testing device for generators and starters. It had a buzzer with headphones that helped to find short-circuits between armature windings. This apparatus had been available since the interwar period, yet it was only used in specialized car electrician workshops.[28]

Most authors agreed that written accounts were of little help to learn diagnostic listening, chiefly because only experience would train a young mechanic's ears. Still, many articles were published to explain the diagno-

25. "Lernt beobachten," 262; "Kontrolle und Diagnose (2. Teil)," 267. In "The Sounds of Science," historian of science Cyrus Mody has shown how scientists in the lab use this sonic ability to monitor the course of experiments.

26. The "Airsonic" stethoscope, for example, could be equipped with either a small tip or a bell. "Ein neues Hörgerät," 463; see also "Auf der Suche nach Geräuschen," 405. For Karin Bijsterveld, "sonic skills" include listening skills and skills to use listening instruments. See Bijsterveld, *Sonic Skills*; see also Pinch and Bijsterveld, "New Keys to the World of Sound."

27. Jonathan Sterne, *The Audible Past*, 87–99.

28. EF 002/005 and EF 003/005, in RB.

sis of automobile sounds. Onomatopoetic description like the above-mentioned sound of a faulty cylinder was a rather rare strategy, even though it seemed to be more common in everyday shop talk.[29] A first step to describe diagnostic listening was the classification of sounds into normal and symptomatic sounds. Next, lists of "standard sounds," such as valve ticking or piston knocks, were often drawn up. These lists were supposed to codify sound descriptions as pinging, knocking, whining, and so on. One exemplary article presented no less than twenty-five suspicious car sounds and their technical causes. Where necessary, the different sounds were further qualified: a knocking sound, for example, was high- or low-pitched, loud or faint, rhythmic or irregular.[30]

The general problem with these codifications was that different designations were used for the same kind of sounds. A well-known case involved engine knocks, sometimes called "pinging" and at other times "knocking." One author nicely summarized these difficulties:

> If someone says "liverwurst" and someone else "black pudding," both will know exactly what the other refers to. But when one driver says "pinging" and the other "knocking," no one will really know if they mean the same thing or something different, nor will even the driver in most cases know what he actually means. If this sounds confusing, it hardly comes as a surprise! Because the terms "pinging" and "knocking"—even after decades of research in this field—are still cluttered . . . and let me assure you, even the experts will have differing opinions on this.[31]

As this quotation suggests, there was not just friction between the ordinary language of automobilists and the relevant discourse of mechanics, but expert mechanics also struggled to label sounds in a clear and unambiguous manner.[32] Jens Lachmund and Melissa Van Drie have described similar problems for physicians when they started to listen to a patient's body with the help of a stethoscope. Doctors struggled with ordering sounds, relating them to particular pathologies, and verbally describing the character of sounds to others.[33]

29. Most interviewees gave some onomatopoetic descriptions, e.g., interview Karl-Heinz Kehrt, interview Manfred Neuner, interview Immo Mikloweit.

30. "25 Geräusche am Auto."

31. Götz Weihmann, "Ping-Ping-Ping, so klingelt es, Pong-Pong-Pong, so klopft es."

32. Siegfried Rauch, "Die Klopfgeister." At the same time it is true that in individual workshops mechanics developed a common vocabulary to speak about car sounds. All my interview partners agreed that their fellow mechanics immediately knew what they meant when they named particular sounds; one interviewee (Helmuth Schultz) mentioned that he once had the idea to write a comprehensive compendium of car sounds.

33. Jens Lachmund, "Making Sense of Sound." To partly overcome these problems, sound recordings were used for educational purposes in the medical field since the 1930s. See Melissa Van Drie, "Training the Auscultative Ear," 177–81.

The difficulties in codifying automobile sounds, as well as the above-mentioned statements indicating that the expert's senses should intuitively or unconsciously register and perceive malfunctions, point at the tacit dimension of automobile diagnosis. Harper has portrayed this aspect of automobile repair as the "kinesthetic sense of the mechanic," a sense that is "[m]arried to the knowledge of materials, [and] produces a working knowledge that stands in stark contrast to the working knowledge produced by formal education." According to Harper, the mechanic's working knowledge can only be acquired through hands-on experience—learning by doing.[34] The technique of diagnostic listening had to be embodied through repeated bodily and sensory exercises. During his repair practice "the apprentice not only has to observe the car but, even more importantly, also pay attention to what his journeyman, his master craftsman does. He needs to observe every single bodily movement of the journeyman, and reflect on why he did it."[35] When, for example, he failed to make sense of his listening experience, he should not be afraid to ask the master craftsman or journeyman for the possible meaning of some unknown sound. What mattered in the end was that from one case to the next the apprentice's experience "would grow."[36] He had to experience for himself "how the success of a repair immediately becomes audible—or, rather, inaudible."[37] Through imitating the work and behavior of senior colleagues, apprentices further embodied diagnostic listening as an exclusive skill that separated experts from non-experts.

To sum up, automobile diagnosis depended on sensory perception, as well as experiential and technical knowledge. The expert ear figured as the most important diagnostic instrument, and the good practice of diagnostic listening revealed what the mechanic's ear and mind had been taught. The discourse on expert senses also demarcated the boundaries of the profession, as ordinary motorists were regarded as incapable of diagnostic listening. Furthermore, mastery of sensory skills distinguished the mature car mechanic from his less-experienced colleagues. In Bourdieu's terminology, it was not the institutionalized cultural capital of the journeyman or master craftsman certificates, but the practical display of embodied cultural capital, in this case diagnostic skills, that structured the hierarchies in the workshop. Thus, diagnostic listening was not only a diagnostic tech-

34. Harper, *Working Knowledge*, 117–33, quote 131; see also Michael Polanyi, *The Tacit Dimension*. Matthew Crawford describes the craftsmen's year-long informal learning process as the gradual establishment of a library full of sounds, smells, and tactile impressions. *Ich schraube also bin ich*, 38–39; see also Zuboff, *In the Age of the Smart Machine*, 40.

35. "Lernt beobachten," 264.

36. "Kontrolle und Diagnose (2. Teil)," 267.

37. "Kontrolle und Diagnose (Teil II)," 236; Manfred Neuner remembered in his interview that the sound of the very first engine he had repaired on his own had been very special for him.

nique, but a social practice, and training the senses concomitantly shaped the mechanics' professional habitus—a point to which I will return in the last section.[38]

Contestation: The Introduction of New Diagnostic Instruments

New diagnostic instruments, like the voltmeter, ammeter, and ohmmeter, as well as various compression and vacuum gauges, were introduced in car repair in the United States in the 1930s. Borg has described it as one answer to the American repair crisis. Motorists were continuously dissatisfied with the quality and price of car mechanics. Car manufacturers and equipment makers tried to solve the distrust between automobilists and mechanics by "scientizing" repair. They "intended these [diagnostic] units to communicate objective facts about a car's condition with unimpeachable authority" and "use the power of display to convince motorists of needed repairs." The whole strategy aimed at "displacing authority from the mechanic to an impressive-looking instrument," thereby turning mechanics into service technicians. In 1934, Ford sold 5,450 so-called Laboratory Test Sets to dealers' shops in the United States. To ensure the success of this approach to "create the mechanics-as-laboratory-technicians," Ford started a massive training campaign. In 1936 alone, about 24,000 mechanics passed the Laboratory Test Set exam. Despite this effort, the new equipment failed to reestablish the shattered service relationship. On the one hand, mechanics were very reluctant to use the new instruments because these "relied heavily on abstract numerical readings from electrical gauges and vacuum gauges which did not fit the practices of most mechanics." On the other hand, the new diagnostic instruments did not solve the bigger problem, the fact that the car mechanics trade was not regulated through trust-building institutions, such as obligatory training courses, certificates, and licenses.[39]

In Germany, new diagnostic instruments were not introduced before the mid-1950s. To better understand this delay, a brief look into the history of the German car mechanics trade is necessary. In the late 1920s, Germany suffered a repair crisis similar to that of the United States. But German car mechanics did not react with the introduction of new technologies as a technical fix; they fiercely lobbied for the institutionalization of an independent trade according to the laws and customs of the German craft professions system. In 1933, after a long struggle with rival ad-hoc

38. For the notions of institutionalized and embodied cultural capital, see Pierre Bourdieu, "The (Three) Forms of Capital."

39. The quotations are drawn from Borg, *Auto Mechanics*, 107–8, 111, 113. Another reaction to the repair crisis was the introduction of a flat-rate repair system. See McIntyre, "The Failure of Fordism."

mechanics, German car mechanics obtained permission to found official craft guilds—with their various legal restrictions, institutions, customs, social relations, and practices.[40] Since the amendment of the trade laws in 1897 and 1908, the different craft guilds were formally in charge of mandatory three- to four-year apprenticeships and with issuing the journeyman's certificate—a sort of passport to the profession—and the master craftsman's certificate—the only license accredited to open a workshop.

In 1934 and 1935, the National Socialists imposed even stricter regulations to strengthen the status of the craft trades.[41] As a result, the car mechanics' trade became an independent craft guild with the obligation to impose all craft regulations. This development restructured the field of car repair, granting the car mechanics' guild the symbolic power to put its seal of approval on those who counted as car repair experts. The "master craftsman's honor" and "high-quality workmanship" provided the two pillars of the German craft tradition: they guaranteed the car mechanics' good practice and the trustworthiness of the profession. In this way the specific German craft tradition helped to establish new sociotechnical hierarchies and institutionalized "trust" between car mechanics and automobilists.[42]

While embracing the German craft tradition, car mechanics also adopted a specific craft ethos and habitus. During their apprenticeship, future mechanics would develop not only the necessary mechanical and sensory skills, but also commitment to good practice and respect for the craft system's hierarchies. Diagnostic skills, like diagnostic listening, became part of the professional jurisdiction of car mechanics. There was a dynamic interplay between diagnostic skills and sociotechnical hierarchies, vocational traditions, and changes in mobility culture. Repair practice can best be described as a social practice that was deeply embedded in Germany's crafts culture, including its aims, customs, and social status. In other words, car mechanics also learned to deploy their bodily skills within a particular social dynamic, whereby rival, ad-hoc mechanics and motorists were readily dismissed as non-experts. Based on the powerful social position of the craft

40. Kevin Borg introduced the notion of "ad-hoc mechanics" to apply to members of other trades, like blacksmiths and bicycle mechanics, who frequently repaired cars in the early days of automobilism. *Auto Mechanics*, 31–52. As of 1897 and then 1908, the right to enter a trade was restricted in Germany. See Wolf-Dietrich Greinert, *The "German System" of Vocational Education*; Bernd Holtwick, "'Handwerk,' 'Artisanat,' 'Small Business'"; see also Richard Sennett, *The Craftsman*.

41. For the tangled history of German craft trades and National Socialism, see Adelheid von Saldern, *Mittelstand im "Dritten Reich"*; Heinrich August Winkler, *Mittelstand, Demokratie und Nationalsozialismus*.

42. Holtwick, "'Handwerk,' 'Artisanat,' 'Small Business'"; see also Sennett, *The Craftsman*, 321–26. For the notion of symbolic power see Pierre Bourdieu, "Social Space and Symbolic Power," 23. For the interwar history of German car mechanics, see Krebs, "'Sobbing, Whining, Rumbling'"; Stefan Krebs, "Automobilgeräusche als Information"; Stefan Krebs, "'Notschrei eines Automobilisten' oder die Herausbildung des Kfz-Handwerks in Deutschland."

guilds, car mechanics thus succeeded in excluding other trades and drivers from car repair.[43] After the Second World War, the military government in the American occupation zone abandoned the regulated craft system and introduced the freedom to practice any trade. The conservative trade guilds, however, viewed this freedom of trade as an undesirable American custom, and they successfully lobbied for a return to the former system. In September 1953, the West German government reinstitutionalized the old regulations of the craft system. This stabilized existing sociotechnical hierarchies, and auto mechanics safeguarded their professional status.

With regard to this different solution to the repair crisis, it is, perhaps, hardly surprising that new diagnostic instruments reached Germany with a delay of two decades. In 1949, in a photo report containing suggestions from American repair practice, the trade journal *Motor Rundschau* presented an engine test set from American manufacturer Sun Electric Corporation. The following year another journal published an editorial titled "Dial Gauge versus Senses 1–0." It presented American diagnostic instruments, "instruments that cannot lie," as being superior to the senses of an expert mechanic. In the author's view, American test equipment conveyed the image of a laboratory setting; such test tools looked "like medical instruments in an operating room, covered in white enamel and chrome, to be wheeled silently towards the patient: the 'sick' automobile."[44]

When in 1954 leading automotive supplier Bosch began to sell diagnostic instruments, it marked a turning point in Germany. Bosch had developed its first test instruments for spark plugs during the First World War, and as of 1925, this company pursued the systematic development of test equipment. However, these instruments were provided only to the company's own service stations, the Bosch-Dienst. If Bosch's early stationary test benches still had a functional appearance, the aesthetic of the new instruments was clearly modeled after the American example. The devices were designed to be visually consumed by motorists, and marketing brochures explained that the imposing look of test sets would help to "convince even the most skeptic customer." Although Bosch and other manufacturers initially advertised that instruments would sell more repairs, they soon chose other arguments, due to the fact that German mechanics were not looking for more customers because they could hardly cope with the existing demand.[45]

43. For the notion of professional jurisdiction see Andrew Abbott, *The System of Professions*. For the development of the German car mechanics' craft see Krebs, "'Sobbing, Whining, Rumbling.'"

44. "Sie fragen—wir antworten." The condemnation of "freedom of trade" belonged to a set of anti-American sentiments, like the depiction of the Nuremberg trials as "winner's justice" (*Siegerjustiz*): "Gewerbefreiheit." For the Sun tester see "Werkstatt-Praxis." The quotation is from "Editorial: Messuhr gegen Gefühl 1:0."

45. In the 1930s, Bosch electrical starters, generators, and other parts of the ignition system had reached market shares of 80 to 90 percent. Walter Kaiser, *Bosch und das Kraftfahrzeug*, 11. See also "Fehler rasch finden durch Testen," 1959, EF 005/004; for the

In the central line of reasoning then taken up, instrument manufacturers argued that a new repair practice was needed to keep up with West Germany's ongoing motorization boom. One author worked out that in big cities, like Hamburg, the ratio of cars to mechanics increased from 27:1 in 1950 to 58:1 in 1962, while the number of repair shops decreased from 546 to 394. And this tendency continued: nationwide the overall number of automobiles soared from 4 million in 1960 to 13.5 million in 1970. In this same period, the number of mechanics increased only from 179,000 to 226,000, and the number of apprentices from 60,000 to 88,000. Approximately 50,000 additional car mechanics were needed to keep up the current service level.[46]

Conversely to what these figures suggest, the car mechanic apprenticeship was still the most popular apprenticeship among young boys, and the number of apprentices was the largest of all trades. If recruitment of new mechanics posed a challenge in the United States because of the profession's low social status, this was not an issue in Germany. However, it could be hard to hire mechanics in Germany because in times of full employment, certified car mechanics earned much higher wages in other areas of the car industry. This meant that ten years after their exam, only 25 percent of the journeymen still worked in the trade. And the traditional trade system hampered the rapid training of more mechanics.[47] Thus, to satisfy demand in the short term, a few repair shops started to hire unskilled laborers, but this move put the uncontested expert status of German car mechanics at risk. In this context, the advocates of diagnostic equipment pointed at its rationalizing capacity. Because test instruments analyzed subsystems without first having to disassemble them, they were supposed to save a lot of time, thus enabling individual mechanics to repair more cars in the same amount of time. Bosch boldly promised that with the help of its test equipment, tasks that used to take "hours of searching" were now a matter of "minutes."[48]

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development during World War I, "Bosch-Zündkerzen-Prüfvorrichtung für den Feldgebrauch," 1914, and "Zündkerzenprüfvorrichtung," 1916, EF 015/013. The quotation is from "Bosch-Motortester EFAW 214 A und EFAW 214 AS 10," 1969, EF 001/009 (all in RB).

46. In 1950, 76,500 vehicles were registered in Hamburg compared with 265,700 in 1962, while the number of mechanics increased from 2,820 to 5,207. Still, this situation compared quite favorably to that in the United States, where the ratio of cars to mechanics increased from 107:1 in 1960 to 120:1 in 1970 (or in absolute numbers: in 1957, there were 135,000 repair shops with 700,000 mechanics in the business). Borg, *Auto Mechanics*, 128–29; "Editorial: Der Engpaß"; "Ein Blick in amerikanische 'repair shops'"; "Die Sorgen mit den vielen Aufträgen."

47. To ensure training quality, the craft system imposed formal restrictions on the number of apprentices a journeyman or master craftsman was allowed to train at the same time. And the long apprenticeship simply delayed any organizational measures to train more mechanics by three to four years.

48. Interview Karl-Heinz Kehrt; interview Leo Franzen; "Editorial: Attacken!"; "Guter Service—leichtgemacht"; see also Orr, *Talking about Machines,* 150–53; for the

The second argument focused on recent and projected changes in automotive technology. It was argued that modern engines were high-powered (several years earlier this was true only of sports-car engines). This increase was achieved through new manufacturing techniques with tolerances as tight as 0.005 mm. To consider these tolerances in the repair practice, mechanics needed to rely on new test and measuring devices. Another recent trend was the increasingly sophisticated electrical system, highlighted by the regular publication of ever more complicated wiring diagrams of new car models. One more development pertained to the use of electronic components: Bosch's electronic fuel injection D-Jetronic, introduced in 1967, already used twenty-five transistors. All these new technologies gave rise to the notion that adjusting the timing and carburetor by listening to changes in engine sound no longer seemed appropriate. But even without the most recent improvements, statistics from the early 1950s revealed that about 40 percent of all defects were caused by the electrical system. Thus, ordinary mechanics increasingly had to have knowledge of electricity and the required test instruments.[49]

Finally, the third argument in favor of test equipment was the introduction of a new service: testing. As one author explained to the *Krafthand* readers in 1954, the new support came from the United States. It was seen as part of good after-sales service, and Volkswagen was the first German manufacturer to copy the idea. Testing was not about diagnosing and locating malfunctions; rather, it was deployed to discover even the smallest deviations from index values to prevent future problems, check engine performance, and keep gasoline consumption low. Motorists were invited to test their cars before departing on a holiday trip, or before the winter season, to ensure that everything was in top condition. All these various tests could only be performed with modern diagnostic equipment. In addition, car manufacturers started to prescribe that their authorized repair shops use certain test equipment for periodical examinations. Volkswagen, in cooperation with Bosch, developed a large test stand with the latest diagnostic equipment. From 1 August 1968, all Volkswagen repair shops had to use this stand when motorists took their cars in for servicing. Other car manufacturers introduced similar test systems soon after.[50]

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employment of unskilled foreign laborers during the period of full employment, see Ulrich Herbert, *Geschichte der Ausländerpolitik in Deutschland*. For the Bosch advertisement see "Bosch senkt ihre Werkstattkosten," 1971, EF 001/010, in RB. A similar comment was published on the cover page: *Kraftfahrzeug-Kurier* 33, no. 5 (1960).

49. Emil Zogbaum, *Unter Motor und Fahrgestell*, 2nd ed., 238. Compare, for instance, "Wiring diagram BMW 1800 T I" and "Wiring diagram Opel-Admiral." "Neues von Bosch"; *Der stationäre Motor-Test*, 5–6. In Germany a particular apprenticeship for car electricians existed; still, these experts usually worked in specialized workshops and not in ordinary repair shops.

50. "Fehler rasch finden durch Testen," 1959, EF 005/004, in RB; "Anleitung zum Testen mit Bosch Testgeräten," 1960, EF 001/007, in RB; "Praktische Winke für die

By the late 1960s, diagnostic equipment was offered by more than forty manufacturers. It consisted of a large number of single-test instruments. Most of these devices measured electric current, even if "dwell angle" or "RPM" was written on the dial. One of the few mechanical instruments was a compression gauge that could be used to test the state of the engine. A significant pressure difference between cylinders indicated, for instance, a leaking valve or broken piston ring. A typical review article in the 1960s listed as many as seventeen essential instruments. These could be purchased as single instruments or integrated into a large test set.[51]

The introduction of new diagnostic equipment clashed with traditional repair practice. As described in the previous section, mechanics were used to relying on their senses and quite simple tools like screwdrivers and caliper gauges to recognize, locate, and fix technical problems. Now they were urged to integrate complex and unfamiliar instruments into their daily practice. Thus, the new technology questioned the status of working knowledge and implicitly contested the position of master craftsmen and older mechanics. These experienced mechanics feared losing their status as skilled experts when they could not display the same competence in handling the new instruments as they could in sensory diagnosis. One trade author observed that older mechanics "are afraid to disgrace themselves, and they feel false shame instead of asking for a second introduction to the proper use of test instruments."[52]

To penetrate the established diagnostic practice and convince mechanics to abandon sensory diagnosis, manufacturers of the new equipment and trade authors, who acclaimed the introduction of the test instruments, leveled criticism at traditional practice. An advertisement for engine test sets simply declared informal or traditional methods of diagnosing and adjusting to be "obsolete."[53] And in an article on automobile diagnosis one author confessed: "Let's be honest, the often cultivated pride of mechanics to detect a flaw or deviation through their sense of touch, or to just have a handle on the engine timing, needs to be discarded. You can no longer master modern automobiles with your expert senses; only with modern diagnostic instruments is it possible to do the necessary tests and adjustments."[54] Frequently, commentators drew a line between old and young

Werkstatt"; "BMW Electronic-Center"; "Diagnostic-Service jetzt auch bei Ford." By the end of 1968, Volkswagen had trained 5,000 mechanics to use the new test stand. "Fortschrittlicher VW-Kundendienst"; He., "Das neue VW-Diagnose- und Wartungssystem."

51. "Testgeräte im Kraftfahrzeugbetrieb." Large test sets were quite expensive and could only be used by a single mechanic at any given time, but they had the great advantage that only a few cables were needed to carry out several tests. Horst Gräter, "Testgeräte."

52. "Fehler bei der Bedienung von Motortestgeräten"; see also "Prüfen und Einstellen."

53. Advertisement F. C. Müller.

54. "Prüfen und Einstellen."

mechanics. One author acknowledged that "[i]n our profession we have some cunning old birds with a sense of touch who can feel a 1/100 mm."[55] And well-known handbook writer Emil Zogbaum elaborated: "[S]ome old hands are really a 'walking' test set. Their ears and senses are perfectly trained so that they can detect problems ordinary mortals cannot even dream of."[56] Still, both authors maintained that even such expert senses never reached the constant precision of measuring instruments, and that younger mechanics were even less trained to use their senses and experience to diagnose malfunctions. The authors did not discuss younger mechanics undermining the workshop hierarchy when they started to use test instruments their older colleagues dismissed as useless, since younger mechanics were socialized to not question the judgment of more experienced colleagues.[57]

Another rhetorical strategy in favor of new diagnosis distinguished between conservative and progressive experts. The latter preferred "measuring instead of guessing, checking instead of trying, and testing instead of sensing."[58] And Bosch seemed to have no qualms about outright criticism of the master craftsman's expert ear, suggesting that the times of diagnostic listening (*Diagnose nach Gehör*) were truly gone. The company claimed that tests based on scientific methods "are the fastest, easiest and most reliable. In contrast to traditional methods, scientific tests provide a clean-cut picture of the engine state."[59] The semantic opposition of subjective and objective diagnostic means that went along with the scientification of car repair was a crucial discursive strand in trying to establish new "diagnostic epistemologies."[60] The new trust in abstract numerical readings can be depicted as a form of "mechanical objectivity." Lorraine Daston and Peter Galison have shown that disciplinary and societal contexts were crucial to establish new notions of objectivity. Following their line of reasoning, the criticism of diagnostic listening can be read as a disapproval of old diagnostic techniques *and* their social practice. The snide labeling of traditional repair methods as "tinkering" is telling here, because such qualification was directly targeted at the self-conception of car mechanics as trained experts.[61] Thus, mechanical objectivity did not contest individual (auditory)

55. "Editorial: Messuhr gegen Gefühl 1:0."

56. Emil Zogbaum, *Unter Motor und Fahrgestell*, 3rd ed., 230.

57. Horst Gräter, *Motor-Test-Praxis,* 15; see also "Die Probefahrt—Unsinn oder Notwendigkeit?"; He., "Unsere Kunden."

58. "Die ganze Werkstatt-Ausrüstung Bosch," 1969, EF 001/009, in RB.

59. "Bosch senkt Ihre Werkstattkosten," 1971, EF 001/010, in RB. The quotation is from "Wir testen mit dem Bosch-Zündungs-Oszillographen."

60. Gräter, *Motor-Test-Praxis*, 15; Borg, *Auto Mechanics*; see also "Kontrolle und Diagnose (Teil III)," 270.

61. Lorraine Daston and Peter Galison, *Objectivity*. Based on Egon Bittner's work, Julian Orr ("Images of Work," 446) also distinguishes between repair techniques and repair practice. In his view, practice includes the whole activity as situated, located, and

perception, but rather the social organization of (sensory) perception.[62] Mechanical objectivity undermined the central position of the expert senses and at the same time questioned the traditional apprenticeship system. However, as I will discuss in the last section, car mechanics did not easily embrace the new values and social norms that came with "objective diagnosis."

Entangled with the new paradigm of objective diagnosis was the visual culture that surrounded the new equipment. Most devices had visual displays with numerical values, yet mechanics were unfamiliar with this type of abstract technical data. They first had to learn the visual skills to read these instruments. Trade journals published numerous descriptions that explained in detail how different instruments worked and how one had to handle them. On a more general level, articles presented, for instance, different types of diagrams such as function graphs and Sankey diagrams. One author explained that diagrams show you, "at a glance," the relation between two or more variables, but also warned that diagrams could mislead you when the scale of the axis was adjusted.[63] To facilitate the appropriation of diagnostic equipment, some devices like the Süko-Triotest had dials with numerical values and a second scale with verbal translations. These translations could be short descriptions of possible problems, technical terms like "lean" or "rich" (mixture), or simply "bad" and "good."[64]

The advantage of visual displays, compared to audible signs, was that journals and handbooks could now use figures to give examples. One manual of an oscilloscope, for instance, presented twenty-six screen shots that showed typical faults. Untrained mechanics were advised to compare these exemplary images with the "normal picture" (*Normalbild*) of a perfect running engine and to memorize these differences.[65] The assumed persuasive power of visual displays built on long-lasting cultural connotations that attributed vision with objectivity and self-evidence.[66] Authors argued that this preference for visual proof was further strengthened by the emergence of the new visual culture of television. The oscilloscope, for instance, was called the mechanics' television (fig. 2). And because car mechanics were familiar with adjusting the picture of their television set at home, they did not need to be anxious about tinkering with the oscilloscope's display. Bosch and Volkswagen even imagined the workshop to be transformed

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positioned in society, whereas techniques are "discrete components of the practice, such as the use of specific tools or perhaps even specific principles. . . ." See also Egon Bittner, "Technique and the Conduct of Life."

62. For the notion of sensory perception as "a form of social organization in its own right," see Charles Goodwin, "Seeing in Depth," 256.

63. "Das Diagramm."

64. "Süko-Triotest-Gerät"; see also "Motordiagnose mittels Vakuumprüfung"; "Testgeräte für die Werkstatt (5)."

65. "Neue Prüf- und Testgeräte auf der IAA."

66. See, for example, Ingold's critique of this Western hierarchization of the senses: *The Perception of the Environment*, 247–50.

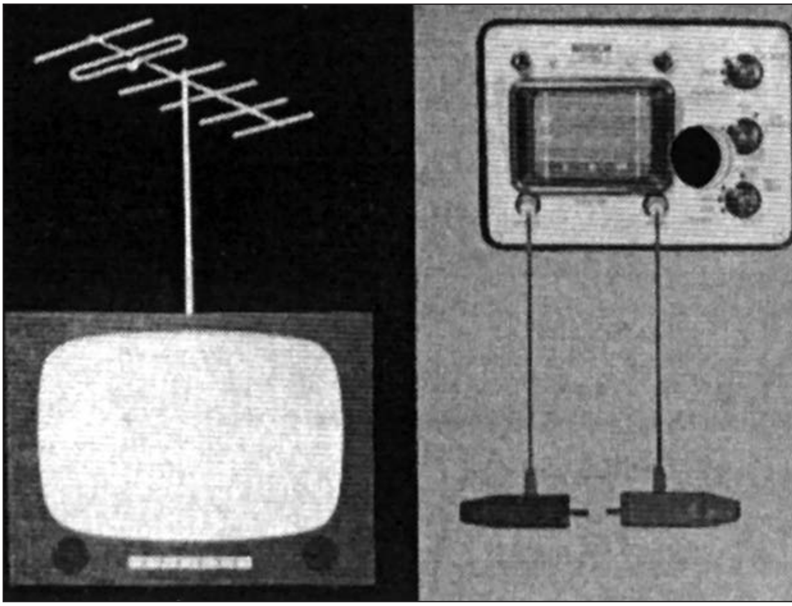

FIG. 2 1960s slide from a Bosch diaporama comparing the oscilloscope with a television set to convince mechanics of the "easy" use of the oscilloscope. (Source: Robert Bosch GmbH, Historical Communication, Stuttgart, EF 005/009. Reprinted with permission.)

into a sort of television studio. In futuristic diagnostic centers, customers would be able to follow the service process on screens in the waiting area—a technical vision that never came true.

To summarize, the introduction of new diagnostic equipment went hand in hand with new repair epistemologies: new (technology-mediated) ways of knowing the car and its subsystems. Abstract numerical readings now described the state of the car, and the comparison of measured with nominal data indicated whether an engine was OK, needed repair, or had to be adjusted back to the manufacturer's specifications. From the perspective of the manufacturers and workshop owners, new car diagnosis, with its paradigm of mechanical objectivity, aimed at the rationalization of car repair practice. From the mechanics' viewpoint, it contested long-established hierarchies, as the display of traditional diagnostic skills would no longer serve as signs of expert competence and seniority in the trade.[67]

67. For the garage as television studio, see *Der stationäre Motor-Test*, 119; He., "Das neue VW-Diagnose- und Wartungssystem"; "Bosch Diagnose Zentrum: Teststraße der Zukunft," 1972, EF 006/004, in RB; "VW MK III/71/B 10-3," 1971, Z 319/10406, in CAVW. For the general trend to rationalize maintenance activities in the first postwar decades, see Konstantinos Chatzis, "Rationalizing Maintenance Activities within French Industry during the Trente Glorieuses (1945–75)."

Resistance: Appropriating the New Diagnosis

Despite the intense propaganda in favor of new diagnosis, many trade authors had to concede that it was quite common for car mechanics not to use the expensive diagnostic equipment at all. In fact, in many workshops the fancy new equipment was left sitting in a corner, gathering dust.[68] One author observed that "[a]fter initial enthusiasm many test instruments are not used in the workshop because the mechanics lack the knowledge to work with them."[69] As a consequence, they increasingly felt helpless, if not outright unwilling, to use diagnostic equipment. Two intertwined reasons can help explain why mechanics resisted the introduction of new diagnostic practices for more than three decades: the German craft tradition, and the technological difficulties of rationalizing car repair.

New diagnosis, as imagined by instrument makers like Bosch, questioned one of the foundations of the German craft system: the socialization of new craftsmen through apprenticeship. If new test instruments would enable semiskilled workers to diagnose malfunctions and then simply change the broken parts, why should car mechanics still be trained for three-and-a-half years? This question was explicitly discussed in trade journals. The answer given underlined that the semiskilled simply lacked the necessary visceral knowledge to overcome unexpected problems: "Every master craftsman knows these 'part changers' are absolutely helpless when they can't get a spare part, and then have to solve the problem in another way." The derogatory term "part changer" was associated with American auto work, a bad result of rationalized car repair. In a travel account, a German mechanic informed his colleagues that actual repair work was rare in the United States: it was expensive and the quality was poor. Other articles criticized, for example, the "American habit" of selling replacement engines, instead of just repairing what was actually wrong, and countered this with the good practice of the traditional cylinder polisher business in Germany.[70] Some authors even recalled the Second World War, euphemistically called the "time of distress," to underline that mechanical skills were invaluable to repair things when no spares are available. And a 1965 *Krafthand* editorial emphasized that, in contrast to the United States, embodied repair skills held priority over changing parts in Germany.[71]

68. "Testgeräte in der Werkstatt"; "Diagnose bei der Inspektion." One interviewee (Franz-Josef Hansen) remembered that an older colleague commented on the request to use an instrument so: "it has no use, I know what the problem is."

69. "Die Technik des Oszillographen," 610.

70. "Moderne Testgeräte für die Automobilwerkstatt"; "Was unterscheidet Sie vom 'Angelernten'?"; "Zur Stellung des Kraftfahrzeughandwerks"; "Autowerkstätten in den USA"; "Austauschmotoren." The quotation is from "Fachlicher Nachwuchs."

71. Caption on cover pages, *Kraftfahrzeug-Kurier*; Hans Wuttkowski, *Service-Fibel für die Kfz-Mechanik*, 8; "Fachlicher Nachwuchs: Eine Lebensfrage für das Kraftfahrzeughandwerk"; "Handwerkliche Fertigkeiten—nach wie vor!" Most interviewees

Learning embodied skills played a crucial role in the socialization of young car mechanics. Beyond shaping a particular skill, for example filing, the repetitive training was meant to instill tidiness, punctuality, care, and meticulousness, as well as overall physical and sensory skills.[72] The mechanics' identity discourse stressed that "metal educates"—*Metall erzieht*. The status of such skills was also reflected in the curriculum: apprentices first had to learn filing, drilling, lathing, forging, and so on. As part of the practical exam before becoming a journeyman, mechanics had to make a simple tool or spare (the so-called *Gesellenstück*) to demonstrate their mechanical skills. Automobile diagnosis as such only became part of the journeyman's theoretical exam in 1965.[73] Ten years earlier, the journal *Krafthand* described Autohaus Jacob Fleischhauer GmbH & Co. KG in Cologne, at that time the biggest car dealer and garage in Western Europe, as a paramount example of a modern workshop. The separate, well-equipped training workshop included a huge section with several chimneys where apprentices learned to forge.[74] Both the training workshop and the apprentice's forging skills were proudly displayed in the company's portrayal. This (self-)representation of car mechanics was quite different from that in the United States. As Borg has commented: "[i]n the context of Ford's campaign to re-create the image of mechanics as scientific laboratory technicians, the ads [from the 1930s and 1940s] discarded the blacksmith as no longer a symbol of respect but now a symbol of backwardness."[75]

In Germany, embodied knowledge featured prominently in the discursive construction of car mechanics' professional identity—whereas diagnostic instruments were hardly mentioned in this context. In particular, stories about sonic skills celebrated and maintained the professional status of car mechanics. Stories in regular columns like "Exchanging Repair Experiences" (*Erfahrungsaustausch*) or "Know-How from Practice" (*Aus der Praxis*) are particularly informative here. Like the war stories of photocopier service technicians analyzed by Lucy Suchman and her colleagues, these columns not only described interesting cases and proposed repair tips, they were an important part of the ongoing identity discourse.[76] The

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stressed the importance of mechanical skills and mentioned the good old times when car parts were still repaired. E.g., interview Franz-Josef Hansen, interview Helmuth Schultz.

72. "Der moderne Betrieb," 377. See also Zuboff for the laboring body as the body that accrues knowledge "in the course of its activity; knowledge inscribed . . . in hands, fingertips, wrists, feet, nose, eyes, ears, skin, muscles, shoulders, arms, and legs": *In the Age of the Smart Machine*, 40.

73. "Kraftfahrzeugmechaniker—Kraftfahrzeugschlosser."

74. In 1953, the Cologne garage counted 51,541 repairs and 36,315 safety inspections. "Der moderne Betrieb," 340. Interviewee Immo Mikloweit worked in this garage.

75. Borg, *Auto Mechanics*, 111.

76. Lucy Suchman, Jeanette Blomberg, Julian Orr, and Randall Trigg, "Reconstructing Technologies as Social Practice," 396; see also Orr, *Talking about Machines*, 2, 125–

Krafthand column "Think Through to the End" (*Zu Ende denken*), acknowledged by the editors as the most popular of the journal, featured "true stories" from mechanics' practice. The narrative structure of these stories followed a common pattern: a seemingly routine repair job soon proves much harder to solve, and the junior car mechanic needs to call in the help of the master craftsman, who, based on his long experience and trained senses, always manages to arrive at the correct diagnosis. One exemplary story, for instance, revealed that three extensive test drives—the last one by the master craftsman, were needed to finally make the correct diagnosis. Another featured a young mechanic who, after failing to solve his first repair job, asked his colleague for help; after briefly listening carefully, this senior expert immediately identified the problem. In yet another episode, mechanics used a stethoscope to establish a preliminary diagnosis of a damaged gear wheel, but the master craftsman, after a short test drive, contested this diagnosis and, of course, was right: even without the stethoscope he could hear with his trained ears that a bearing at the rear axle was broken. All these stories conveyed the message that diagnostic skills distinguished experienced mechanics from junior colleagues and that formal differences in the workshop hierarchy "naturally" equaled differences in skill level.

Whereas the above stories emphasized that a master craftsman's long experience and status were reflected in his superior listening skills, others clarified that a mechanic's trained ear was better than the ears of ordinary automobilists. Typical tales first described a motorist's wrong self-diagnosis and the mechanic's subsequent corrective judgment. In confirming the expert's listening skills, these narratives celebrated the mechanic's professional ethos and prestige. They also reminded him that mechanics always had to display their (collective) competence in the presence of customers. Younger colleagues, for example, were warned against questioning the diagnosis of more senior colleagues, as this could shake the motorist's trust. On the other hand, solving an audible nuisance demonstrated the mechanic's sonic competence: to please his customer's ears, one mechanic preferred to dismiss the car manufacturer's prescriptions. He encouraged his colleagues to increase the specified valve clearance by another 0.10 mm to avoid valve ticking that often annoyed drivers. This anecdote underscores that repair is not just about cars and mechanics, but about cars, mechanics, and customers. It also shows that based on their extensive working knowledge, car mechanics sometimes knew the actual performance of car engines better than the engineers who designed them.[77]

26, and 142–43. Most interviewees told anecdotal stories about failed diagnosis; they also emphasized the importance of sharing such stories with colleagues. See, for example, interview Karl-Heinz Kehrt; interview Manfred Neuner; interview Franz-Josef Hansen; interview Immo Mikloweit.

77. "Zu Ende denken [A]"; "Zu Ende denken [C]"; "Zu Ende denken [D]"; "Erfah-

The last anecdote points at the situatedness of car repair and leads to my second argument on why new diagnosis could not easily penetrate German car repair practice: diagnostic instruments did not meet the practical needs of car repair. Some new test instruments simply lacked precision; in addition, measuring results were often obscured through handling errors. In practice, it did not really matter whether operating errors were caused by lack of knowledge or usability; in either case, the data measured were likely to produce an incorrect diagnosis. To avoid this, mechanics had to operate with great care, which is why in many instances the use of test instruments proved more time-consuming than advertised. The tedious aspects of their operation also hampered smooth integration of test devices into the daily repair routine.[78]

Furthermore, car mechanics struggled with the interpretation of test results. Although manufacturers promised that they simply needed to compare measured data with index values, mechanics also had to take the usual wear and tear into account. When, for instance, was an engine's compression so low that a general overhaul was needed? To analyze measuring results and draw the right conclusions, mechanics needed much experience. In the end, test instruments only gave abstract numerical information and mechanics still had to learn to trust the displayed data. The screen of the oscilloscope was particularly difficult to interpret; the information displayed seemed to be written in "cipher." One article about "the fear of using the oscilloscope" explained that "aversion to the oscilloscope is mainly an aversion to the screen picture mechanics cannot 'read.'" Although manufacturers tried hard to make their test instruments more accessible, critics anticipated that many mechanics simply would not be able to work with these tools. Because of these technical shortcomings, diagnostic instruments challenged the car mechanics' self-perception as competent practitioners, and, more importantly, mechanics feared that customers could notice this insecurity linked to the use of new equipment.[79]

The failure of the Volkswagen diagnosis system is further revealing. The "diagnosis I" system was introduced in 1968, a series of prescribed tests to be performed on a standardized test stand. The mechanic was urged to fol-

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rungsaustausch"; He., "Unsere Kunden"; K. A., "Erfahrungsaustausch," 656; one of the interviewees (Immo Mikloweit) mentioned that some car mechanics wore their stethoscopes around the neck as status symbols. For the same attitude of American mechanics, see Borg, *Auto Mechanics*, 152; see also Sterne, *Audible Past*, 98; Orr, "Images of Work," 444; Orr, *Talking about Machines*, 108.

78. Hans Jörg Leyhausen and Bruno Kierdorf, *Service-Fibel für die Kfz-Diagnose*, 10; "Moderne Testgeräte für die Automobilwerkstatt," 105; "Fehler bei der Bedienung von Motortestgeräten"; "Aus der Werkstatt"; see also Orr, "Images of Work," 443–45; Orr, *Talking about Machines*, 73.

79. "Moderne Testgeräte für die Automobilwerkstatt," 106; see also interview Helmuth Schultz; "1x1 des Bildschirms"; "Elektronische Motortester—das Richtige für die Werkstatt." The quotation is from "Warum die Angst vor dem Oszillographen," 5.

low every single step in the test routine and to note down all results in a report to be presented later to the customer as objective proof.[80] However, some months after the introduction of the new system, the Volkswagen market research division admitted in a report that a majority of the workshops under investigation disliked the new system. Workshop owners complained about its unreliability: to cope with the manifold technical problems they had to assign their most experienced mechanics for the job. From the owners' perspective, testing belonged to the unproductive side of the workshop, and they were not keen to "lose" their best man on the productive side—the actual car repair.[81]

The situation became even worse with the introduction of "diagnosis II" in 1971. Developed together with computer manufacturers AEG and Siemens, it was based on a computer diagnosis that included eighty-eight single checks; twenty-two were automatically done by the system. The other sixty-six had to be performed by a specially trained test mechanic. The system prescribed every single test step, and the mechanic had to communicate his test results back to the computer using a remote control. The computer diagnosis was presented as "machines controlling machines," yet at the same time, the machine also controlled the mechanic. He could not skip any test steps, and the automatic printout rigidly documented every action he performed. With much fanfare, Volkswagen announced the aim of computer diagnosis: the guaranteed "flawless diagnosis" (fig. 3). But the actual diagnostic practice showed a different picture.[82] An internal report admitted that mechanics had to perform a traditional diagnosis after the automatic test, because automatic measurements (e.g., of camber or compression) were inaccurate and, in addition, erroneously interpreted by the computer.[83]

In his letter to Volkswagen's CEO, Rudolf Leiding, one workshop owner complained that "measurements are false or inaccurate, the trained mechanics reject the diagnosis system, because they only get indefinable numbers and measurements. . . . Our mechanics told us that the computer used in the training program did not function either. . . . And now, the people from Siemens are telling us that on this [technical] basis we will never

80. Before the introduction of computer diagnosis, test reports were already perceived as an instrument to control car mechanics. When obliged to use test cards, mechanics could no longer "forget" to perform all planned checks. In this sense, visual proof was not only a means to convince drivers of necessary repairs, but also a means for employers to control the work of their employees, and for car manufacturers to control the work of affiliated workshops.

81. Central Market Research, "VW Diagnose Studie," October 1968, Z 69/415/2; Advertisement, 1968, Z 103/95/16 (both in CAVW); He., "Das neue VW-Diagnose- und Wartungssystem."

82. For advertisements and press coverage see Z 103/95/13, Z 103/95/14, Z 103/95/15, Z 103/95/18, Z 103/95/21, Z 103/95/30, and Z 174/1337/1 (all in CAVW).

83. Even a 50-percent compression difference between cylinders was diagnosed as OK. "Report VW-Computer-Diagnose," no date, Z 69/284/1, CAVW.

FIG. 3 Advertisement for the "Volkswagen-Computer-Diagnosis," ca.1971. (Source: Company Archive Volkswagen AG, Wolfsburg, Z 103/95/22. Reprinted with permission.)

get accurate measurements." At the end of his letter he worried: "My motivation to address you is my great concern that everybody will lose faith: our mechanics, and in particular our customers."[84] According to this letter, new diagnosis, instead of raising confidence, posed a serious threat to the trust relationship between motorists and car mechanics. Another owner of a large workshop added that diagnosis II took even more time than diagnosis I.[85] Moreover, the computer fascinated motorists, but also raised (unfulfillable) expectations. And in the end, the mechanic with his senses, still the "best measuring instruments," had to fix the car—not the computer.[86]

84. Letter from G. Gall to R. Leiding, 19 November 1971, Z 69/284/1, CAVW.

85. Another criticized aspect was the necessary investment. The diagnosis system II cost 10,000 DM or a monthly leasing rate of 300 DM. "Minutes Dealer Association Advisory Board Meeting," 17/18 September 1970, Z 174/153/1, CAVW. In the 1960s, test instruments cost between 3,000 and 15,000 DM. Some test stands were even more expensive: the capital expenditure for a dynamometer was about 40,000 DM. This was roughly the same price as the complete equipment of a small conventional workshop with four to five mechanics. An internal calculation from Bosch estimated that a garage needed a daily throughput of at least thirty cars to pay off a dynamometer. For comparison: at that time the average annual income in Germany was about 6,000 DM. "Welches Testgerät für welchen Zweck?"; "Editorial: Die Sorgen mit den vielen Aufträgen"; "Kraftfahrzeughandwerk und Konjunktur." Some interviewees also lamented the costs for test equipment: see interview Manfred Neuner; interview Leo Franzen; interview Helmuth Schultz. For the calculation, see "Bosch Werkstatt-Ausrüstung Werbeinformation," 1974/75, EF 011/001, in RB.

86. Letter from G. Heinze to R. Leiding, 4 October 1971, Z 69/284/1, CAVW.

An internal investigation confirmed the disastrous picture: inaccurate automatic measurements and unreliable computer analysis. Members of the Volkswagen board found themselves in a dilemma: the diagnosis system was advertised as being more important than a new car model, hence abandoning computer diagnosis would be a huge blow to Volkswagen's image. Therefore, the board decided to continue computer diagnosis, but also to discourage motorists from using the system.[87] The firm did not communicate the problems with diagnosis II to the public; however, the company's internal communication no longer presented the diagnosis system as a substitution for car mechanics, but admitted that it required skilled experts. Car mechanics reacted with a clear rejection of the diagnosis system. Another Volkswagen report noted that in most garages test instruments were ostentatiously not used. Even in 1979, Horst Gräter, author of a seminal handbook on "engine test practice," was still pessimistic, believing that the compression gauge was probably the only diagnostic instrument used in all repair shops. Thus the 1970s showed an ambiguous picture: on the one hand, car manufacturers (not only Volkswagen) obliged workshops to buy more and more test equipment; on the other hand, a majority of car mechanics clearly rejected these instruments. As one journalist summarized: test systems, in particular computer diagnosis, were nothing more than "Potemkin villages."[88]

Conclusion

The introduction of new diagnostic equipment in the German car mechanics trade shows that a history of technology-in-use can tell us a more complex story than appears on the surface. From car and instrument manufacturers' (publicized) information and associated articles in trade journals, one could get the impression that since the 1950s new diagnostic technologies, due to their superior diagnostic power, smoothly substituted for the working knowledge of German car mechanics. However, the (social) practice of car repair paints a rather different picture: because of the strong resistance of German mechanics, the widespread use of diagnostic instruments was delayed by more than three decades. The local context—the distinct German craft tradition—predetermined the long and difficult appropriation process. When young car mechanics started their apprenticeships in the 1950s and 1960s, they learned to train and mold their five senses into expert senses. Diagnostic listening was perceived not

87. Initially, the test service was free (the first 40,000 kilometers), but beginning 1 January 1975, it was offered only at the owner's expense.

88. "Minutes Board Meeting," 3 October 1972 and 10 October 1972, Z 373/166/1; see also "VW-Computer-Diagnose," no date, Z 69/284/1; brochure "VW MK III/71/B 10-3," 1971, Z 319/10406; brochure "Was Sie über Diagnose wissen sollten," no date, Z 971/1/17; "10th EKDL conference," October 1973, Z 971/1/48; R. Straub, unknown title, *Mot* 12/1971: 46–48, in Z 174/1337/1 (all in CAVW). See also Gräter, *Motor-Test-Praxis*, 27.

only as a legitimate but as a privileged entry to troubleshooting and repair knowledge. And training the senses was more than learning a technique: it served as a means both to accustom apprentices to the social practice of the trade and to embody the "dispositions" of an expert mechanic. Professional sensory skills should be understood as situated social practices, shaped through the perceptual framework of the trade. Mechanical and sensory skills constructed and maintained hierarchies in the repair shop, and they demarcated experts from non-experts. Thus diagnostic listening stood in metonymically for the profession's monopoly of competence.

Contesting diagnostic skills through new diagnostic technology challenged one of the foundations of the profession and explains why German car mechanics rejected new diagnosis for a long time. The German example further illustrates that the "middle ground" of car repair, this "ambiguous space between production and consumption" is not "impervious to social acclaim."[89] The normative value of the German craft system not only granted car mechanics high social status but also enabled stable and trustful relationships between mechanics and customers. In this context, it is revealing that Germany, in contrast to the United States, did not suffer a repair crisis in the 1960s, despite the contestation of traditional car repair practice and critical garage tests by consumer activists, daily newspapers, and public television.[90]

However, German car mechanics could delay but not stop the introduction of new diagnosis. The advance of the "regulated" electronic automobile forced the use of new diagnostic technology. The maintenance of electronic fuel-injection systems or electronic controlled-spark timing required special test devices. The development of electronic fuel injection was propelled by the announcement of stricter emission regulations in the United States and Europe. Volkswagen, for instance, considered the use of electronic fuel-injection systems to meet strict California clean-air regulations, if it would not change the general engine layout; this plan was implemented only on its top-tier models. For the domestic market, with less rigid emission standards, German car manufacturers benefited from Bosch's leading role in developing fuel-injection systems for small, high-efficiency engines. By the late 1970s, more than ninety models from eighteen German car manufacturers used electronic gasoline-injection systems from Bosch.[91]

This technological change forced the introduction of new diagnostic

89. Borg raises the question of whether the middle ground is impervious to social acclaim: *Auto Mechanics*, 2–3, 174; see also footnote 6.

90. For the reassessment of professionalism as normative value, see Julia Evetts, Harald Mieg, and Ulrike Felt, "Professionalization, Scientific Expertise, and Elitism," 110–11. For the 1960s repair crisis in the United States, see Borg, *Auto Mechanics*, chap. 6. For critical tests of German repair shops, see, e.g., "Attacken"; "Gewußt wie . . ."; "Kann man sich auf die Werkstatt verlassen?"; MC, "Der große Werkstatt-Test"; "Kein schönes Ergebnis."

91. For the rise of the regulated automobile, see Tom McCarthy, *Auto Mania*, 171–206. Initially, all Volkswagen models were to be equipped with electronic fuel-injection

epistemologies. For the car mechanic, electronic systems were sealed black boxes, and sensory experience no longer served as a valid entrance to diagnostic knowledge.[92] The "electronic" automobile, in other words, significantly changed the structure of the car repair field. The position of manufacturers and employers was strengthened, and they gained more control over car mechanics. Furthermore, the knowledge to handle test devices became a new form of cultural capital, while new certificates for specially trained test mechanics altered the hierarchy in the workshop. However, new diagnosis no longer raised doubt concerning the social organization of the trade as the German discourse on diagnostic equipment changed significantly during the 1970s. It was no longer presented as accessible to semiskilled workers; only long-trained experts could handle and read modern test instruments. Modern mechanics still knew how to diagnose without any instruments, but they also mastered the use of diagnostic instruments without fear of being degraded to the low status of "part changer."[93]

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systems. In the end, the company equipped only its top-of-the-line Type 3 cars with fuel injection, as a cheaper carburetor solution became available for other models. "Minutes Board Meeting," 30 August 1966, Z 373/455/1/4, CAVW. In Germany, fuel injection aimed at fuel economy rather than emission control. Walter Kaiser, "Clean Air Act and American Automobile Industry." In 1978, electronic fuel injection reached a market share of 16.2 percent in Germany, compared to 6.5 percent in Europe and only 0.7 percent in the United States. Dr. S., "Gedanken zur Zukunft der Benzin-Einspritzung"; see also Kaiser, *Bosch und das Kraftfahrzeug*, 11–116.

92. "Weiterentwickelte Jetronic-Kraftstoffeinspritzung von Bosch"; "Kontaktlose Transistor-Zündanlage"; see also interview Manfred Neuner, interview Immo Mikloweit, and interview Franz-Josef Hansen; Harper's mechanic Willie complained that the system was "sealed," one could only check the sensors, that's it. Harper, *Working Knowledge*, 129.

93. Gräter, *Motor-Test-Praxis*, 308; "Was unterscheidet Sie vom 'Angelernten'?"; "Kfz-Handwerker—auch in Zukunft ein interessanter Beruf"; "Was sie über Diagnose wissen sollten," no date, Z 971/1/17, CAVW.

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