»Automation in Agriculture«, 1965

Technological Innovation from the Field

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In the paper »Automation in Agriculture«, published in the journal *Outlook on Agriculture* in 1965,[1] K.E. Morgan, a member of the Farm Mechanization Department at the British University of Reading, outlines a Kuhnian paradigm shift[2] for the agricultural sector. Since agriculture, inherently, has always been shaped by environmental relations and has produced environmental knowledge, Morgan considers the possibilities for automating a dedicated environmental practice. Addressing Morgan's essay, I argue that, seen from a Science and Technology Studies perspective, agriculture can also be understood, both practically and discursively, as a historical space that significantly initiated environmental technology developments and in which the relationships between environment and technology have been continuously addressed. From its very beginning, agriculture has fundamentally been characterized by the cultivation of environments into cultural landscapes and has itself significantly triggered and shaped technological innovation. This is illustrated by the historical case study of the ›self-driving tractor‹. Agriculture can be regarded as an epistemic space of innovation, whose technological developments only later diffused into other societal areas, as is briefly traced using the example of autonomous driving.

After a prolonged era of mechanization, Morgan wondered, had the time come for agricultural automation, a time ripe for »widespread automation as a sequel to mechanization?«[3] Ten years had passed, Morgan noted, since the term »automation« was first used in agriculture. In other areas, the stages of automation were easy

1 See Morgan, K. E.: »Automation in Agriculture«, in: Outlook on Agriculture 4/6 (1965), p. 295–301. The journal *Outlook on Agriculture*, first published in 1956, is dedicated to developments in agricultural science for an interdisciplinary readership.

2 See Kuhn, Thomas: The Structure of Scientific Revolutions, Chicago: University of Chicago Press 1962.

3 K. E. Morgan: »Automation in Agriculture«, p. 295.

to trace, as Morgan illustrated with a prototypical factory, delivering a condensed teleology of industrial manufacturing with humans as the decisive point of reference.[4] Morgan described four stages of industrial automation: first, the provision of mechanical power to support human muscle power (»augment human muscle«), second, the provision of automatic machines to support human abilities (»augment human skill«). The third stage of industrial automation involved the provision of instruments to support the human sensory system (»augment human senses«), and the fourth would be the availability of decision-making machines to support human thought (»augment human thinking«).[5]

In agriculture, technological development followed a similar path, albeit with its own characteristics, according to Morgan: the slow development of tools and machines that were pulled or driven by humans and animals was followed by a phase of motorization, in which various steam engines and combustion engines began to supplement the muscle power of humans and animals. The motorization phase culminated in the production and widespread use of agricultural tractors, which had become *the* hallmark of modern agriculture. The development of increasingly complex yet more compact tractors – equipped with hydraulic lifting gear etc. – enabled the construction of machines that were tailored to and compatible with certain tractors, so that they could work together as integrated units.

In agriculture, field work includes transporting machinery, seeds, pesticides and fertilizers to the fields; moving machinery over or through the various raw materials to process them; and transporting the finished product back to the farm. At the time of Morgan's writing in 1965, agricultural production relied on the operation of semi-automated field machines: »Automatic potato planters, precision seeder-units, sugar beet toppers and band sprayers are in regular use.«[6] Morgan illustrated the area of agriculture as both a cultural landscape and a technological environment, a mediascape, in which organic substances and living organisms – soil, fruit and animals – are consistently measured. It is astonishing how advanced the agricultural machinery described by Morgan already was:

> »Research reports include descriptions of moisture meters, based on neutron scattering, capacitance and spectral absorption techniques. Strain gauges, hydraulic dynamometers and load cells are commonplace. Backfat measurements

4 Morgan's arguments were fully in line with the media theory put forward by Marshall McLuhan just one year earlier, which understands technology as extensions of man. The philosopher of technology Ernst Kapp argued along these lines as early as 1877; see Kapp, Ernst: Grundlinien einer Philosophie der Technik. Zur Entstehungsgeschichte der Cultur aus neuen Gesichtspunkten, Braunschweig: Georg Westermann 1877; McLuhan, Marshall: Understanding Media. The Extensions of Man, New York: McGraw Hill 1964.

5 K. E. Morgan: »Automation in Agriculture«, p. 295.

6 Ibid., p. 296.

can be made by ultrasonic means, lean/fat ratios have been determined by measuring radioactive potassium contents. Strain gauge tensiometers and soil resistance blocks are used to measure soil moisture; an ›artificial leaf‹ is used to measure humidity and transpiration losses. Electronic instruments screen 5000 peas per second, distinguish between stones and potato tubers by their relative opacity to Xrays, and between clods and potatoes by their differing reflectance characteristics. A variety of photoelectric devices screen and sort eggs, fruit, seeds and vegetables for internal and external faults, or grade fruit and vegetables for ripeness. Lettuces are squeezed to determine which have hearted sufficiently, while asparagus tips are measured to determine which are long enough to be harvested. Instruments listen outside beehives to predict when the bees will swarm; they detect tramp iron in hay, water in milk, and watch outside turkey runs to warn of the approach of burglars. Instruments are available for measuring the spectral responses of insects and the thixotropism of butter.«[7]

To use Morgan's teleological model, agriculture around 1965 was at a point where semi-automatic machines were already augmenting human skills and even senses, and were able to exceed them in speed and quality; they allowed the datafication of what was inaccessible to human senses. True automation and the paradigm shift that it would entail, however, would be characterized, according to Morgan, not only by *detecting* errors in the day-to-day operation of a farm using sensitive technologies, but also by *correcting* them: »Automation implies decision-making machines capable of choosing between alternatives that are different in kind, not merely in degree, and the delegation of control to these machines«; and this »decision-making« in turn had an explicit environmental dimension, because it manifests itself in »the control of quantities and conditions, as in environmental control«.[8]

The discussion of automation in the realm of agriculture was, of course, not unique to the British context. The topic was also widely debated in Germany: In 1968, Wilhelm Batel – former director of the Institut für landtechnische Grundlagenforschung at the Forschungsanstalt für Landwirtschaft in Braunschweig – published a paper on the fundamentals of automation in agricultural production, which begins by providing a minimal definition: »Automation is understood to mean the takeover of certain areas of formerly human activities through technical means.«[9] Alone, this aspect of delegating agency to technological objects is not sufficient to adequately characterize the phenomenon of automation in contemporary

7 Ibid.

8 Ibid., p. 297.

9 My translation. The original German reads: »Unter Automatisierung versteht man die Übernahme bestimmter Bereiche ehemals menschlicher Tätigkeiten durch technische Mittel.« Batel, Wilhelm: »Grundsätzliche Überlegungen zur Automatisierung der landwirtschaftlichen Produktion«, in: Grundlagen der Landtechnik 18/1 (1968), p. 14–20, here p. 14.

understanding. According to Friedrich Pollock – co-founder of the University of Frankfurt Institute for Social Research, representative of the so-called Frankfurt School as well as author of the first comprehensive study on automation – the escalation of the »era of automation« in the history of technology, as compared to previous industrial revolutions, consists in the fact »that *machines* are able to guide and control *other* machines«.[10] While human practice was the reference for progressive automation according to Morgan and Batel, autonomous machine dialog is the central novelty of realized automation: machines that communicate with and regulate other machines.

In retrospect, it is hardly surprising that automation was consistently linked to environmental factors in agricultural discourse; after all, farmers are constantly working in the literal field. For the referenced machinery, this also meant that automated technologies could not be conceived without their environmental interrelations. While it is plausible, in the historical context, to think of technical media – e.g. radio sets, telephones, televisions – fundamentally as encapsulated artifacts that are not dependent on their situated environments, it was agriculture that had to adapt early on to the natural conditions of the operating environments of its machinery.

The uncertainties of the agricultural field became constitutive for new technologies to be developed, as Morgan explains with reference to the »difficulties caused by variable environmental conditions, the extensive out-of-doors nature of many production processes«: »Agricultural inputs, such as sunlight, rain, genes and bacteria, are almost uncontrollable«.[11] The automation of agriculture proved to be more complex than that of a factory production line, because, according to Batel, in agri-

10 Pollock, Frederick: Automation. A Study of its Economic and Social Consequences, translated by W. O. Henderson and W. H. Chaloner, New York: Frederick A. Praeger 1957 [my emphasis]. The book is considered the first comprehensive socio-critical study of automation, first published in German in 1956 and later translated into several other languages. The English version of the book contains the following definition of automation: »The word has various synonyms such as ›cybernetics‹, ›automatic control‹, ›control engineering‹, ›automisation‹ and many more. It appears, however, that ›automation‹ is now ousting the other words as an expression denoting a technical development which is replacing human labour by machinery in factories and workshops in a way that would have been thought impossible only ten years ago.« Ibid., p. 3. Pollock characterizes the »era of automation« as follows: »The aims and methods of automation may be provisionally defined as a technique of production the object of which is to replace men by machines in operating and directing machines as well as in controlling the output of the products that are being manufactured.« Ibid., p. 5. The original German publication is: Pollock, Friedrich: Automation. Materialien zur Beurteilung der ökonomischen und sozialen Folgen (= Frankfurter Beiträge zur Soziologie, vol. 4), Frankfurt a.M.: Europäische Verlagsanstalt 1956.

11 K. E. Morgan: »Automation in Agriculture«, p. 297.

cultural production, the materials to be produced and the agricultural environments are a »living matter«.[12]

As much as cybernetic approaches sought to equalize technological-informational and physiological-biological processes,[13] agricultural practice could not easily be translated into mechanistic theory. Whereas Morgan's work is characterized by an explicit optimism regarding technology and progress, Batel's work reveals a decidedly agronomic skepticism. Fundamentally, the problem with agriculture, he writes (albeit in cybernetic rhetoric), is »that complex bio-cybernetic and engineering-cybernetic systems are intermeshed« and there is a general »difficulty of recognizing and understanding the parameters of biological processes«.[14] The agricultural fields, as ›uncontrollable‹ factors, interfered with the formalization of environments by means of technological process operations which did not take into account their situatedness.

This led to the emergence of a new epistemic order of technology in agriculture. In the philosophy of technology of the 19th and early 20th centuries, it was still largely common to regard technology as a ›weapon against nature‹ or at least to interpret it as a means of ›mastering and overcoming space‹.[15] Now, a conceptual homogenization of technology development and environmental conditions became necessary. For the automated driving of tractors, for example, this meant that optimal driving routes could not be determined beyond the field, because this did not take into account any imponderables of the field itself: »In practice«, in contrast to idealizing theory, one tractor »could be bumped off course and require correcting while the other may not«.[16] Therefore, it should be argued from an STS perspective, it became necessary to conceptualize the development of technology and environmental factors as being in an ongoing mutual interrelation, since environment and technology mutually shape each other through processes of translation, inscription, and enactment.

12 W. Batel: »Grundsätzliche Überlegungen«, p. 15. The terminology of »living matter« – »lebendige Materie« – also has to be critically read due to its usage in National Socialism; see, for example, Dreidax, Franz: »Lebendiger Boden – ewiges Volk«, in: Leib und Leben (October 1938), p. 199–205.

13 See Wiener, Norbert: Cybernetics. Or Control and Communication in the Animal and the Machine, Cambridge, MA: MIT Press 1948.

14 My translation. W. Batel, »Grundsätzliche Überlegungen«, p. 19. For a more in-depth look at the historical concept of automation and its entanglement with cybernetic theory, see Routhier, Dominique: With and Against. The Situationist International in the Age of Automation, London/New York: Verso 2023.

15 See, for example, Knies, Karl: Der Telegraph als Verkehrsmittel. Mit Erörterungen über den Nachrichtenverkehr überhaupt, Tübingen: Verlag der Laupp'schen Buchhandlung 1857; or Spengler, Oswald: Der Mensch und die Technik. Beitrag zu einer Philosophie des Lebens, München: C. H. Beck 1931.

16 K. E. Morgan: »Automation in Agriculture«, p. 298–299.

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For Morgan, as for Batel, the tractor was key to automation in agriculture. Tractors were the agricultural machines that were produced in sufficient numbers to keep the costs of the control units attached to them low; in addition, they were the machines used for all crops and for the entire farm all year round. Considerations about the automation of agriculture almost culminated in the subject of the automated tractor. Accordingly, in the historical context of the publication of Morgan's »Automation in Agriculture«, the debate about automatic tractors was widely publicized, and various patent specifications for their formalization exist.[17]

Morgan himself was involved in developing a prototype self-driving tractor that was publicly demonstrated in 1961. The self-driving of the vehicle was realized by means of a system of leader cables laid in the ground, which guided the tractor along certain predetermined routes.[18] The tractor could drive along these wires for a certain distance, increasing precision and working speed in field work. Accordingly, the reports at the time emphasized that the fundamental novelty of the »automatic tractor« or »Robotug« was that it operated »without a driver«.[19] The electronically guided tractor, it was further stated, »can find its own way around a farmstead« thanks to »sensing coils«.[20]

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17 See, for example, Gilmour, W. D.: »An Automatic Control System for Farm Tractors«, in: Journal of Agricultural Engineering Research 5/4 (1960), p. 418–432; Widden, M. B./Blair, J. R.: »A New Automatic Tractor Guidance System«, in: Journal of Agricultural Engineering Research 17/1 (1972), p. 10–21; Mikhaylov, V./Suprunenko, B./Yankevich, V.: »A Radio-Controlled Tractor«, in: Radio 8 (1959), p. 17–18; Richey, C. B.: »Automatic Pilot for Farm Tractors«, in: Agricultural Engineering 40/2 (1959), p. 78–79; Brooke, D. W. I.: »Automatic Guidance System with Wide Spaces Leader Cables«, in: Farm Machine Design Engineering (1969), p. 36–39; Buckingham, F.: »Robot Mechanical Plowing«, in: Implement and Tractor (December 15, 1962), p. 10–11; Cox, S. W. R.: »Automation in Agriculture«, in: Control 9 (1965), p. 247–252; Edwards, G.: »No Driver for this Tractor«, in: Engineering 207/5382 (1960), p. 87; Finn-Kelcey, P. G.: »Automation in Agriculture«, in: Farm Mechanization 18/201 (1966), p. 41–42; Helps, F. G.: »Driverless Tractors for Materials Handling«, in: Radio and Electronic Engineering 25 (1968), p. 273–275; Jones, P.: »Parson Builds Driverless Tractor«, in: Farmers Weekly (May 3, 1963), p. 57; Liljedahl, L. A./Strait, J.: »Automatic Tractor Steering«, in: Agricultural Engineering 43 (1962), p. 332–335, here p. 349.

18 For a more detailed historical investigation of the origins of such a »cable navigation«, namely in maritime environments at the beginning of the 20th century, where, however, human navigators were crucially involved, see Borbach, Christoph: »Signal Environments & Proximity Sensing. Lines of Navigation in Subsea Space, ca. 1920«, in: Konstantin Haensch/Marie-Louise James/Matthias Planitzer (eds.), Uncanny Environments, Hamburg: Textem 2025 [in print].

19 Brockington, P. A. C.: »Electronic Vehicle Control is a Reality«, in: Commercial Motor, June 23, 1961, p. 726–727, here p. 726.

20 Ibid., p. 727.

One type of »self-navigating control«[21] of the tractor could go beyond static leader cable systems and be realized through infrared transmitters, which would allow for flexible guidance. The environmental dimension of autonomous driving was highlighted as the central engineering achievement, because what could be realized in the open field would be »relatively simple«[22] to achieve in limited environments such as depots or railway infrastructures. However, the realization of autonomous navigation with analog sensor technology proved to be unreliable in the agricultural field due to, for example, uneven terrain. As this brief example shows, the environment did not present itself as a passive entity that supposedly needed to be actively shaped; rather, in the agrarian space, it developed a specific *agency* – a power to act of its own. The environment itself became ›active‹ and normative for the development of future technologies.

Besides the specifics of quite disparate proposals for how a self-driving tractor might be realized,[23] it is remarkable that the competing or even diverging concepts are united on an epistemological level in that they intended to achieve navigational autonomy. Of course, one could counter that the automation of transportation technology began much earlier. This can be seen in the automobile or the cockpit of the airplane, which have increasingly become technologized spaces.[24] Unlike these, however, the automated tractor was not intended to assist a human navigator through technological affordances, but to navigate *by itself*.

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The discourse on the automated tractor and the model experiments of its testing in the agrarian field ultimately led neither to broad implementations nor to satisfactory solutions. Nevertheless, the automated tractor of the 1960s should not be seen as a story of failure of a potential technological innovation. In this context, the fundamental relationship between humans, technology, and environments was at stake. The epistemic conviction emerged that automation should not be limited to systems that supposedly operate independently of their environments, but that autonomous technical systems should in fact take into account and interact with specific environments. Technologies and environments were conceived of as co-designed.

21 Ibid.

22 Ibid., p. 726.

23 An overview of the benefits and drawbacks of various systems for automating tractor movement is provided by Warner, M. G. R.: »The Automation of Agricultural Field Work«, in: Proceedings of the Institution of Mechanical Engineers, Conference Proceedings 1964–65 (1964), p. 295–324.

24 See Mattern, Shannon: »Mission Control: A History of the Urban Dashboard«, in: Places, March 2025, https://placesjournal.org/article/mission-control-a-history-of-the-urban-dashboard/.

The self-driving tractor symbolizes more than the endeavor towards automation and labor-saving devices, that is, the replacement of physical with mechanical labor. The early experiments with self-driving tractors in the testing grounds of agricultural fields are rather representative of a new order of knowledge in agriculture. As a *pars pro toto* example, the self-driving tractor can be considered a central agricultural medium, in that it does not function as a neutral ›tool‹ in the relationship between humans and their environments, but actively models new orders: it is representative of the mutual production of environmental and technological knowledge.

Agricultural fields were the sites of an increasingly automated shaping of nature by technological systems; likewise, the environmental factors of agricultural fields became constitutive for the realization of technological mobility. To put it somewhat more loosely, environmental factors and technological tractors became mutually determining for each other. The material fields of agriculture could therefore be interpreted as the fields of a now-tendential media landscape. Experiments with self-driving tractors can be seen as the first step towards an agricultural order in which nature and technology merge into one self-regulating system, as is currently being discussed in digitally networked systems in agriculture under terms such as ›smart farming‹ or ›precision farming‹ by Big Tech companies. The rudimentary automation and control technology of the 1960s foreshadowed a future in which machines would not only work autonomously, but also could collect and analyze information about their environment through feedback loops, and react to changing situations independently and flexibly.

Following the maxim of Louis Emrich, the author of the first comprehensive German treatise on automation, that automation itself would be a »foreshadowed future«,[25] it can also be stated that in this context, concepts were tested that would only much later diffuse into other areas of practice. If one adopts the thesis that the agricultural sector, which has so far been largely neglected by media-historical research, can be understood as an epistemic space that both initiated basic technological research and had a lasting influence on further developments, then the experimental practice and theory of self-driving tractors in the 1960s becomes particularly interesting when linked to the history of the automobile,[26] and particularly relevant for the context of the current reality of so-called autonomous driving:[27] the automated tractor is an emblematic motif of such self-driving objects. For most of

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25 »Die Automation ist ja selbst vorausgegriffene Zukunft!«; Emrich, Louis: Fabriken ohne Menschen. Unsere Zukunft im Zeichen der Automation, Wiesbaden: Betriebswirtschaftlicher Verlag Dr. Th. Gabler 1957, p. 5.

26 See Möser, Kurt: Geschichte des Autos, Frankfurt a.M.: Campus 2002.

27 See Sprenger, Florian (ed.): Autonome Autos. Medien- und kulturwissenschaftliche Perspektiven auf die Zukunft der Mobilität, Bielefeld: transcript 2021.

its history, the automobile has relied on a human driver, who had to constantly monitor the vehicle's surroundings.[28] Of course, *automated* driving as attempted by the self-driving tractors of the 1960s is not the same as *autonomous* driving by today's standards.[29] However, the ›self-driving capability‹ of the early tractors of the 1960s had a symbolic significance: they were the first attempts to replace humans as direct-control actors with automated, environmental systems.

Furthermore, the discourse and practice of automated driving in the 1960s were sustainable at a fundamental level, since they generated acceptance for practiced forms of automated mobility. Beyond the agricultural field, self-driving technical objects remained largely a science fiction for at least another two decades. In the history of technology, notable advances include the development of a car with a camera-based ›vision system‹ at the Universität der Bundeswehr in Munich in the 1980s by a research team led by engineer Ernst Dieter Dickmanns, with the aim of enabling autonomy in navigation. At the time, Dickmanns set himself apart from other approaches in computer science and artificial intelligence, preferring to select relevant image sections in the most recent camera images rather than capturing the entire surrounding of a car. Apart from this system's technological specifics, it is significant that Dickmanns, a recognized pioneer in the history of automotive autonomy, pinpointed his inspiration for self-driving cars as coming from the agricultural field.[30]

Agriculture can be seen as a space for innovation, in which new technologies are tested that only later diffuse into mainly urban areas and gain relevance beyond the limited space of the agricultural field. Or, as reporting on the »automatic tractor« of the 1960s already envisioned: »These successful applications of electronic control to farm tractors and industrial trucks may be indicative of developments in the fairly near future of far-reaching importance to the road-vehicle industry.«[31] The agricultural sector can thus be understood as an epistemic space that presents itself as a testing environment for technological developments and prefigures further technological advances.

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Also interesting is the reference to sensing, which is explicit in the above-mentioned sources, especially when paralleled with current debates on sensors and their omnipresence. We are confronted today with a situation in which sensors

28 See Kröger, Fabian: »Das Automobil als Sehmaschine«, in: ibid., p. 167–185, here p. 167.

29 See Kröger, Fabian: From Automated to Autonomous Driving. A Transnational Research History on Pioneers, Artifacts and Technological Change (1950–2000), Cham: Springer 2024.

30 I owe thanks to Dinah Pfau for this reference. Cf. podcast »Alte Schule« #95 with Ernst Dieter Dickmanns, May 13, 2021, https://www.youtube.com/watch?v=YBaoTwJAA2s.

31 P. A. C. Brockington: »Electronic Vehicle Control is a Reality«, p. 726.

are ubiquitous, at least in Western or ›Global North‹ societies. In his book *Sensing Machines*, Chris Salter notes that in 2022, there were between thirty and fifty billion sensors operating across the globe, compared to only 7,8 billion people.[32] Sensors are now an essential part of logistics networks and internet-of-things technologies, where RFID tags track goods along global supply chains; they are also a fundamental part of our everyday navigation practices through miniaturized GPS receivers. This sensorization applies not only to objects, but also to environments, in which potentially everything of economic, political, logistical, legal, geographical, or ecological interest is being digitized. This applies to the measurement of environmental qualities such as storm strengths and wind directions; noise, rain, and air quality; energy generation and management, to name just a few examples. In view of these recent developments, media scholars such as Florian Sprenger conclude that environments in the 21st century are becoming media themselves, while media are becoming environmental at the same time.[33] Sensors, in summary, make environments algorithmic and ultimately sensitive.[34]

Agriculture, however, has always been fundamentally based on cultural techniques[35] and thus on the technologization of environments. The claim that technologies become environmental not only applies to recent technological phenomena, but, as a focus on agriculture shows, has a history of its own. This history, in the agricultural sector – despite current discourses on data-driven farming, precision farming, or smart farming – begins not with the widespread use of digital computers, but rather is characterized from its very beginning by the technical cultivation of land, that is, by environmental techniques. If the scientific study of the environment describes the process by which natural environments are increasingly analyzed, classified, and shaped by scientific methods, concepts, and institutions, it is clear from the history of agriculture how closely this process is linked to the technological transformation of agricultural systems, as evoked among other things by the automatic tractor.[36]

32 See Salter, Chris: Sensing Machines. How Sensors Shape Our Everyday Life, Cambridge, MA: MIT Press 2022.

33 See Sprenger, Florian: Epistemologien des Umgebens. Zur Geschichte, Ökologie und Biopolitik künstlicher environments, Bielefeld: transcript 2019.

34 See Hörl, Erich: »Introduction to General Ecology: The Ecologization of Thinking«, in: Erich Hörl/James Burton (eds.), General Ecology. The New Ecological Paradigm, London: Bloomsbury 2017, p. 1–73.

35 For a broader perspective on cultural techniques, see Siegert, Bernhard: Cultural Techniques. Grids, Filters, Doors, and Other Articulations of the Real, New York, USA: Fordham University Press 2015.

36 This work was supported by the Collaborative Research Center »Media of Cooperation« [Deutsche Forschungsgemeinschaft (DFG) – Project number 262513311].