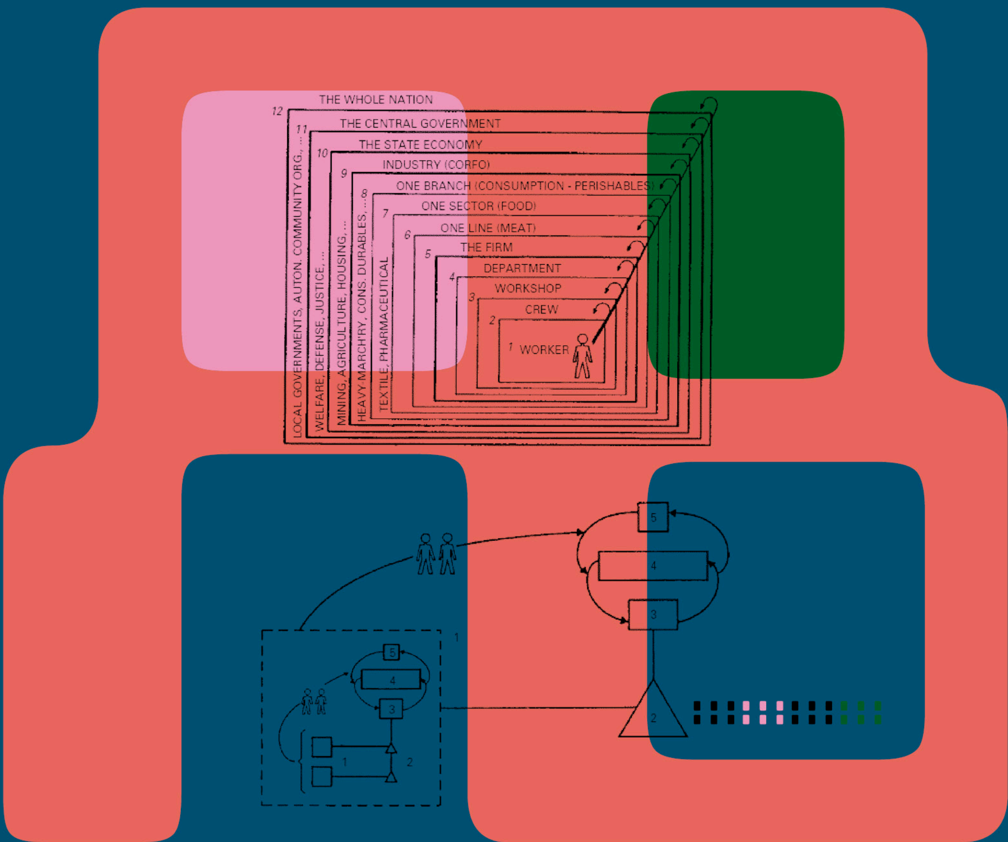
Cybernetics for the 21st Century

Vol. 1: Epistemological Reconstruction

Edited by Yuk Hui



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Cybernetics Across Cultures: The Localization of the Universal

Slava Gerovitch

The history of cybernetics is a story of crossing cultural, political, and disciplinary boundaries. Cybernetics, or the science of control and communication in the animal and the machine, was articulated in the 1948 book of the same title by Professor of Mathematics at the Massachusetts Institute of Technology, Norbert Wiener. A display of Wiener's historical photographs and documents is placed in the hall of the MIT Mathematics Department, not far from my office.

Wiener's work on cybernetics draws on his wartime research on anti-aircraft gun control. He designed and built an anti-aircraft predictor, a feedback-operated servomechanical device for predicting the trajectory of an enemy airplane. This function was usually performed by human gun-pointers and gun-trainers, and Wiener's device would therefore 'usurp a specifically human function'.[1] This work led Wiener to the far-reaching analogy between the operation of servomechanisms, feedback-based control devices, and human purposeful behaviour. In 1943 Wiener, physiologist Arturo Rosenblueth, and engineer Julian Bigelow, jointly published an article in which they suggested that purposeful human behaviour was governed by the same feedback mechanism that was employed in servomechanisms.[2] Combining terms from control engineering (feedback), psychology (purpose), philosophy (teleology), and mathematics (extrapolation), they constructed a classificatory scheme of behaviour equally applicable to human action and machine operation.

1 Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1961 [1948]), 6.

2 Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow, 'Behavior, Purpose and Teleology', *Philosophy of Science* 10 (1943): 18–24.

Cyberspeak between human and machine

In his book *Cybernetics*, Norbert Wiener further generalized these ideas and introduced a new, 'universal' language, which I call cyberspeak. It tied together a diverse set of human-machine metaphors. Cutting across various disciplines—computing, information theory, control theory, neurophysiology, and sociology—cybernetics described living organisms, control and communication devices, and human society in the same cybernetic terms: information, feedback, and control.

Travelling across the Atlantic Ocean to Europe and then to the Soviet Union, cybernetics changed its guise multiple times: it appeared at different times and places as an instrument for devising sophisticated weapons, a theoretical underpinning for the freedom of speech, a method for designing intelligent machines, a model for describing the functioning of the human brain, a vehicle of interdisciplinarity, and a tool for reforming the theoretical apparatus of a wide range of life and social sciences with formal models from mathematics and computing. At times it was filled with strong ideological messages, at other times it was presented as allegedly politically neutral. Every time cybernetics crossed a new cultural, political or disciplinary boundary, its connotations were questioned, and new ones attached.

The universalist aspirations of cybernetics and artificial intelligence

One particularly salient example of cyberneticians' universalist aspirations is the design of computer programmes capable of carrying out some human cognitive tasks, known as artificial intelligence (AI). The aspiration of AI is to grasp the universal principles of thought in order to implement them in a computer. In 1984, Patrick Winston articulated the goals of AI research as follows: 'Artificial Intelligence excites people who want to uncover principles that all intelligent information processors must exploit'.[3] At the same time in the Soviet Union, a budding AI community formulated its own goals, which sounded remarkably

3 Patrick Winston, *Artificial Intelligence* (Reading, MA: Addison-Wesley, 1984 [1976]), 2–3.

similar: 'to understand how the human being thinks, what are the mechanisms of thought'.[4] On both sides of the Iron Curtain, AI research was understood as a search for fundamental principles of human thinking.

Both American and Soviet scientists believed that there existed a general, universal, ahistorical mechanism of human thought. Yet as these scientists themselves belonged to different cultures, they had distinct, culturally specific intuitions about human thinking. The 'humans' whom they took as universal categories were, in fact, people who belonged to specific cultures. Their AI models thus reflected the specificity of their cultures.

Everyday practice in the USA and the USSR

Everyday practice in any society is based on commonly accepted patterns of behaviour—actions perceived as typical and normal—and also on various strategies of handling daily situations, known as common sense. John McCarthy famously called AI systems 'programmes with common sense', implying that a fundamentally universal common sense knowledge underlies human thinking.[5] As the anthropologist Clifford Geertz suggested, however, common sense is 'historically constructed and… subjected to historically defined standards of judgment. It can… vary dramatically from one people to the next. It is, in short, a cultural system'.[6] Geertz warned against 'sketching out some logical structure [that common sense] always takes, for there is none', thus unfortunately undermining McCarthy's basic premise.[7]

Everyday practice serves as a mediator for the constant exchange of cultural symbols, and shapes the cultural vocabulary for any given group. For Americans during this period, everyday experiences ranged from reading *The New York Times* to watching political debates on television to shopping at supermarkets that stocked a great variety of products. Soviet people's everyday experience looked quite different.

4 Mikhail S. Smirnov, ed., *Modelirovanie obucheniia i povedeniia* (The modelling of learning and behaviour) (Moscow: Nauka, 1975), 3.
5 John McCarthy, 'Programs with Common Sense', in *Semantic Information Processing*, ed. Marvin Minsky (Cambridge, MA: MIT Press, 1968), 403–9.
6 Clifford Geertz, 'Common Sense As a Cultural System', in *Local Knowledge: Further Essays in Interpretive Anthropology* (New York: Basic Books, 1983), 76.
7 Ibid., 92.

They never read *The New York Times*, never watched political debates, and never had a problem choosing which brand to buy. They read *Pravda* and underground literature, sat at Party meetings, and stood in lines at food stores. What seemed typical and normal to them looked peculiar and exotic to Americans, and vice versa. Yet even if common sense is not universal, AI models do tell us something—if not about the fundamentals of human thinking in general, then perhaps about specific cultural constructions of common knowledge.

Cultural influence manifests itself not only through typical patterns of behaviour and strategies of everyday life, but also through language, via the metaphors by which we live and think, including thinking about thought itself.[8] In this essay, I discuss the different cultural metaphors for thought prevalent among American and Soviet intellectuals and explore their connections with specific AI systems. I argue that deep cultural factors lie beneath the considerable differences in the approaches to AI developed by American and Soviet scholars. While looking for general principles of thinking and behaviour, AI specialists actually implemented their own cultural stereotypes in their models.

Different cultural metaphors for freedom: choice vs creativity

If we consider such an everyday situation as shopping, the main problem for American customers is how to make the right (one may say, 'healthy') choice among an appealing variety of foods and goods. The ability to make the right choice is also a very important part of academic training in the United States. College students choose most of their courses from a great variety of courses being offered; routine multiple-choice tests require selecting one right answer among several possibilities. Election ballots list multiple candidates for every office.

By contrast, most everyday situations in the Soviet Union left the citizen no choice at all. Higher education curricula prescribed a fixed, pre-determined sequence of courses for every major. The only choice students had was in selecting a preferred athletic activity. Multiple-choice tests were rare. Instead, the student was required to spell

8 George Lakoff and Mark Johnson, *Metaphors We Live By* (Chicago: University of Chicago Press, 1980).

out all the intermediate steps, and if the algorithm was inefficient (or simply different from the one in the textbook), the grade was lowered, even if the answer was correct. Election ballots always included only a single candidate, to simplify political choices. And finally, the Soviet way of shopping posed a different sort of problem for the customer. The problem was not what to choose, but how to find anything at all. With the shortage of many foods and household items, sought-after products could be obtained only via back channels. An ordinary Soviet citizen had to create a unique, long chain of informal social interactions through a network of friends, relatives, friends of relatives, and relatives of friends, so that a desired washing machine or a television set could be found at the other end.[9]

Cognitive psychological theories developed by American and Soviet scholars reflected the different cultural values of choice and creativity. The American cognitive psychologist Jerome Bruner, for example, described concept attainment as a process whose every step 'can be usually regarded as a choice or decision between alternative steps'.[10] Bruner's work showcased the 'cognitive revolution' in psychology, closely associated with the work of the American AI pioneers Herbert Simon and Allen Newell, who placed choice at the heart of their 'heuristic search' model of intellectual activity.

The Soviet psychologist Andrei Brushlinskii, by contrast, rejected the idea that thinking involved a choice among pre-existing alternatives. He argued that true thinking must produce a new alternative: 'Actual live thinking, for example, solving a task or a problem, always takes the form of prediction of an initially unknown, future solution. This prediction... makes the act of choosing among alternative solutions unnecessary'.[11]

AI specialists in the Soviet Union and in the United States sometimes drew on psychological theories, and sometimes psychologists drew on AI models. More habitually, however, AI specialists ignored psychologists' findings, believing that knowledge should flow from AI

9 See Alena Ledeneva, *Russia's Economy of Favours: Blat, Networking and Informal Exchange* (Cambridge: Cambridge University Press, 1998).

10 Jerome Bruner, *Beyond the Information Given: Studies in the Psychology of Knowing* (New York: Norton, 1973), 151.

11 Andrei Brushlinskii, 'Pochemu nevozmozhen "iskusstvennyi intellect "' (Why 'artificial intelligence' is impossible), *Voprosy filosofii* (Problems of philosophy) *no*. 2 (1979): 62.

to psychology, not the other way around.[12] When AI and psychology agreed, this often happened because they both relied on the same cultural stereotypes.

Bureaucratic man: striving for control of the social environment

One of the pioneers of American AI, Herbert Simon, explicitly referred to everyday experience when arguing that at the centre of intellectual activity was an act of choice:

> None of us is completely innocent of acquaintance with the gross characteristics of human choice, or of the broad features of the environment in which this choice takes place. I shall feel free to call on this common experience as a source of the hypotheses needed for the theory about the nature of man and his world.[13]

Simon drew on a wide array of mathematical theories that offered various formalizations of choice in well-structured environments—econometrics, game theory, operations research, utility theory, and the statistical decision theory—which his biographer Hunter Crowther-Heyck has termed 'the sciences of choice'.[14] All these theories assumed the act of choice to be free and rational: an individual acted upon the environment, but the environment did not affect the individual's goals or preferences.

12 Newell and Simon, for example, prophesied in 1958 that 'within ten years most theories in psychology will take the form of computer programs, or of qualitative statements about the characteristics of computer programs'; Allen Newell and Herbert Simon, 'Heuristic Problem Solving', *Operations Research* 6, no. 1 (1958): 7–8. In 1970, Allen Newell described AI as 'theoretical psychology', whose role was to generate problems for experimental psychologists to study; see Allen Newell, 'Remarks on the Relationship Between Artificial Intelligence and Cognitive Psychology', in *Theoretical Approaches to Non-numerical Problem Solving*, ed. Ranan B. Banerji and Mihajlo D. Mesarovic (Berlin: Springer-Verlag, 1970), 363–400.

13 Herbert A. Simon, 'A Behavioral Model of Rational Choice', *The Quarterly Journal of Economics* 69, no. 1 (February 1955): 100.

14 Hunter Crowther-Heyck, *Herbert A. Simon: The Bounds of Reason in America* (Baltimore: Johns Hopkins University Press, 2005), chap. 3.

Simon also borrowed from another set of disciplines: sociology, social psychology, anthropology, and political science. These 'sciences of control', by contrast, emphasized the malleability and docility of an individual, subjected to group and societal pressures and moulded by his social environment. The 'administrative man' of the sciences of control seemed utterly incompatible with the 'economic man' of the sciences of choice.

Drawing on both the sciences of choice and the sciences of control, Simon developed a theory of 'bounded rationality'. One could solve complex problems by reducing them to a limited set of alternatives and choosing rationally among them. Belonging to an organization limited an individual's choices and thus made rational decision-making possible.

In his 1956 paper, 'Rational Choice and the Structure of the Environment', Simon used the metaphor of a maze to introduce a mathematical model describing how an organism could meet a multiplicity of needs, making a sequence of rational choices at branch points, based on incomplete information.[15] This was not merely a convenient description. Extrapolating from his personal experience to the whole of humanity, Simon regarded a sequence of rational choices as a 'universal' model, a philosophy of life:

> A philosophy of life surely involves a set of principles. … Principles can provide a book of heuristics to guide choice at life's branch points, a thread to keep one on the right path in the maze. … In this chapter, I have been describing my life, and also my personal life philosophy, but I have also been describing the life of Everyperson.[16]

In the 1950s and 1960s, Simon and Allen Newell developed the heuristic search approach, which quickly became the dominant paradigm for American AI research. According to their model, problem solving activity consisted in finding a path from the initial to the goal state within the problem space. This space looked like a branching tree or a labyrinth; at every step of the process, the problem solver had to

15 Herbert A. Simon, 'Rational Choice and the Structure of the Environment', *Psychological Review* 63, no. 2 (1956): 129–38.

16 Herbert A. Simon, *Models of My Life* (New York: Basic Books, 1991), 360, 363.

choose one of the alternatives—one of the branches that diverged at the point of choice. In the absence of complete information about the labyrinth, or if the labyrinth was too large to make a feasible calculation, Newell and Simon suggested using heuristics—rules of thumb—to help make the right choice. They believed that labyrinth search was a universal model of intelligence and considered their computer programme, the 'General Problem Solver', to be a general 'theory of human problem-solving'.[17]

As Simon and Newell's conceptualization of human behaviour grew increasingly formal, the model situations they were drawing on became increasingly circumscribed and regulated; from semi-independent decisions by workers in big organizations, to semi-automatic actions of machine-bound operators in air defence control centres, to chess players' limited repertoire of permissible moves. In various computer implementations of the heuristic search model—the theorem-proving Logic Theorist, a chess-playing programme, and the 'universal' General Problem Solver—Newell and Simon tended to focus on situations with complete, unambiguous, computer-friendly descriptions.

Newell and Simon redefined the problem of choice: they no longer spoke of 'making decisions', but rather about 'solving problems'. If the decision-maker could consider different goals, the problem-solver had to focus on the assigned problem. Decisions turned into 'a less contentious, less political, process of allocating "processor time" to different tasks. Choices were now less decisions about which set of values to accept and more decisions about what set of data to process'.[18] Politics was reduced to technology: the liberal aspiration to control and purposefully transform the environment turned into a purely technical task of simplifying search in a labyrinth.

When elaborating her cultural 'grammar' of American storytelling, the anthropologist Livia Polanyi emphasized 'control' as one of the most important categories of American life. 'Proper people' as they are portrayed in everyday conversations, are those who 'can *control* the world sufficiently to be happy and have power'.[19] In the Soviet case,

17 Allen Newell and Herbert A. Simon, 'GPS, a Program that Simulates Human Thought', in *Computers and Thought*, ed. Edward A. Feigenbaum and Julian Feldman (New York: McGraw-Hill, 1963), 279.

18 Crowther-Heyck, *Herbert A. Simon*, 214.

19 Livia Polanyi, *Telling the American Story: A Structural and Cultural Analysis of Conversational Storytelling* (Norwood, NJ: Ablex, 1985), 140 (emphasis original).

by contrast, your social environment was something that could potentially control you, rather than something you could control. If one constructed a Soviet cultural grammar, this description could probably be rephrased as 'proper people are those who can sufficiently escape control by the world to be happy'. The independent-minded intelligentsia's everyday struggle for intellectual autonomy was translated, in a formalized and abstracted form, into Soviet AI models.

The Soviet controversy over 'thinking machines'

The idea that computers that could perform intellectual tasks stirred serious controversy in the Soviet Union in the early 1950s. In the paranoid Cold War context, scientific and technological innovations coming from the West were often viewed with great suspicion. In reaction to the popular discussions of 'thinking machines' in the West, the Soviet press condemned this idea as both a potential technological threat and an ideological subversion. Soviet journalists berated the capitalists for their hidden agenda to substitute a robot for a striking worker and to replace a human pilot who refused to bomb civilians with an 'indifferent metallic monster'. Soviet philosophers, for their part, attacked the idea of 'thinking machines' as both 'idealistic' (detaching thought from its material basis in the brain) and 'mechanistic' (reducing thought to computer operations). Soviet critics lumped all controversial uses of computers under the rubric of 'cybernetics' and labelled this field a 'reactionary, idealistic pseudo-science'. Despite its glaring logical contradictions—cybernetics was portrayed as both idealistic and mechanistic, utopian and dystopian, technocratic and pessimistic, a pseudo-science and a dangerous weapon of military aggression—the campaign had a serious impact on Soviet research. As a result of the media frenzy, work on 'thinking machines' became ideologically unacceptable, and early Soviet computer applications were limited to scientific calculations.[20]

20 On the Soviet anti-cybernetics campaign, see Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (Cambridge, MA: MIT Press, 2002), chap. 3.

Soviet cybernetics: a movement for reform

The anti-cybernetics campaign did not dampen the interest of Soviet scientists in computer systems that could perform intellectual tasks. All of the first large electronic digital computers in the Soviet Union were installed at defence research institutions, which were relatively protected from ideological pressure and also gave their employees access to most recent Western publications. Early Soviet champions of cybernetics and AI largely came from these institutions. The mathematician Aleksei Liapunov led the computer programming department at the Division of Applied Mathematics of the Mathematical Institute of the Soviet Academy of Sciences in Moscow. This division (after 1966, the Institute of Applied Mathematics) performed calculations for the Soviet nuclear weapons and rocketry programmes. These calculations were double-checked against the results obtained at Computer Centre No. 1 of the Ministry of Defence, where the computer specialist Anatolii Kitov was in charge of research and development. In 1955, taking advantage of the thawing political climate after Stalin's death, Kitov and Liapunov teamed up with the leading mathematician for the nuclear weapons programme, Sergei Sobolev, and published an article in the journal *Problems of Philosophy*, in which they publicly dismissed ideological charges against cybernetics and effectively legitimized research in this field.

As the cybernetics movement grew in strength, it brought under its umbrella all sorts of mathematical models and computer applications in 'cybernetic biology', 'cybernetic physiology', 'cybernetic linguistics', 'cybernetic economics', and many other fields. In 1960 Norbert Wiener attended a conference in Moscow and became an instant star. Party leaders became interested in computer technology and the prospects it opened for the socialist economy.

The pendulum of Soviet public attitudes toward 'thinking machines' swung in the other direction.[21] The Soviet press began extolling the intellectual abilities of the computer, portraying it as an all-powerful magical tool for solving any problem. Articles entitled '"Thinking" Machines' and 'Bordering on Science Fiction' mushroomed on the pages of newspapers and popular magazines. Journalists quickly dismissed

21 On the Soviet cybernetics movement, see Gerovitch, *From Newspeak to Cyberspeak*, chaps. 4–6.

the previous ideological critique by claiming that it applied only to capitalist society:

> If in the capitalist world the introduction of 'thinking' machines means the growth of unemployment, exploitation of workers, and fear of the future, in a socialist society, by freeing people from hard, uninteresting work, machines would provide an opportunity to focus on something lofty and joyful—to think, to create, and, in particular, to create new 'thinking' machines.[22]

The new 1961 Programme of the Communist Party of the Soviet Union proclaimed that 'cybernetics, electronic computers and control systems will be widely applied in production processes in industry, building and transport, in scientific research, planning, designing, accounting, statistics, and management'.[23] The Soviet media began calling computers 'machines of communism'.[24]

Despite the media hype, the Soviet government showed little interest in supporting AI research. The leaders of the cybernetics movement distanced themselves from AI aspirations, trying to cultivate an image of the computer as an efficient tool, rather than an autonomous agent. The chairman of the Cybernetics Council of the Soviet Academy of Sciences, engineer admiral Aksel Berg, publicly proclaimed that electronic computers 'will be increasingly providing help to man, but will never replace him and *will never think*'.[25] Computer time remained in short supply, and supervisors did not look favourably on computer programmers' attempts to divert valuable computational resources to investigate problems that aroused their own intellectual interest.

The tenuous position of Soviet AI was reflected in the language. The phrase 'thinking machines' was always put in quotation marks to stress its metaphorical meaning. The very term 'artificial intelligence'

22 Iu. Petrovskii, 'Na grani fantastiki' (Bordering on science fiction), *Znanie–sila* (Knowledge is power) no. 7 (1956): 23–24.

23 *Programme of the Communist Party of the Soviet Union. Adopted by the 22nd Congress of the C.P.S.U. October 31, 1961* (Moscow: Foreign Languages Publishing House, 1961), 66.

24 Viktor D. Pekelis, 'Chelovek, kibernetika i bog' (The human, cybernetics, and God], *Nauka i religiia* (Science and religion) no. 2 (1960): 27.

25 Aksel I. Berg, 'Problemy upravleniia i kibernetika' (Problems of management and cybernetics) (1961), in Berg, *Izbrannye trudy* (Selected works) vol. 2 (Moscow: Energiia, 1964), 87 (emphasis original).

remained controversial, and researchers avoided it. They preferred more neutral-sounding vocabulary, such as ‘cybernetic psychology’, ‘the study of information processes’, or ‘heuristic programming’.[26]

The freedom not to choose

In 1964, when the mathematician Dmitrii Pospelov and the psychologist Veniamin Pushkin brought together computer specialists and psychologists interested in AI for a regular colloquium at the Moscow Power Engineering Institute, they named their field ‘psychonics’. The psychonics group directly challenged the Simon-Newell model of thinking and put forward an alternative approach.

The term ‘psychonics’ was formed by analogy with bionics. While specialists in bionics hoped to imitate the ‘design’ of living organisms in engineering systems, Pospelov and Pushkin aspired to use psychological knowledge to construct intelligent computers. Pushkin conducted a number of eye-movement tracking studies of chess players and concluded that each player constructed a different mental model of the position on the board, rather than searching for the solution in a preset problem space. He asserted that the human problem space is not initially structured like a tree, and that the process of finding a solution involves creating a new problem space rather than ‘pruning useless branches’, as in the Newell-Simon labyrinth model.[27]

Soviet AI specialists disliked the labyrinth model not for its inefficiency, but for its departure from their cultural expectations. Even without knowing the conceptual origins of the General Problem Solver, they associated it with the ‘bureaucratic apparatus’ of labyrinth search. While some followed Newell and Simon’s logic and asserted that ‘the human being thinks by exhaustive search’, many others suggested alternative models, for example, thinking as a chain of associations.[28]

Pushkin and Pospelov conceptualized thinking not as a search, but as a reflection of and on the problem. They argued that the descriptions

26 Evgenii I. Boiko et al., ‘Kibernetika i p roblemy psikhologii’ (Cybernetics and problems of psychology), in *Kibernetiku—na sluzhbu kommunizmu* (Cybernetics in service of communism), ed. Aksel I. Berg, vol. 5 (Moscow: Energiia, 1967), 314–50.
27 Veniamin Pushkin, *Psikhologiia i kibernetika* (Psychology and cybernetics) (Moscow: Pedagogika, 1971), 204.
28 Aleksandr Kronrod, *Besedy o programmirovanii* (Conversations about computer programming) (Moscow: URSS, 2001), 168, 139.

of the current situation and of the goal are often formulated in different terms. In the case of chess, for example, the initial position is described in terms of the location of specific pieces on the board, while the goal state—a checkmate—requires a higher-level description involving the inability to move the checked king. The human chess player must be able to go back and forth between low-level and high-level descriptions, that is, to build and manipulate various mediating models of the situation. Pushkin and Pospelov argued that situation modelling, rather than labyrinth search, was the basic intellectual procedure: 'Among all the existing words and notions used to describe productive thinking, the most adequate, the most suitable is the Russian word *soobrazhenie* (reflection/imagination). … The solution *reflects* the situation, based on the *images* or models of its elements'.[29]

For Pospelov and Pushkin, human creativity manifests itself in abandoning the old labyrinth, re-conceptualizing the problem, and constructing a new problem space. For example, one cannot construct four equilateral triangles out of six matches if one seeks the solution on a plane. Constructing a new labyrinth of solutions—in the three-dimensional space—would produce the answer.[30]

While Newell and Simon started with a ready-made structure of the problem, Pushkin and Pospelov suggested that structuring the problem was an essential intellectual step in finding a solution. Building an adequate model of the situation was more important than powerful search algorithms. Pushkin and Pospelov proposed a semantic language for formal descriptions of the situation at various levels of generality and developed a system for building relational situation models. Pospelov and his team implemented this approach in computer systems for controlling loading operations in a sea port and other industrial operations, which combined technological and human elements.[31]

Pospelov and Pushkin's critique of the labyrinth theory echoed the Soviet cultural perception of choice as a restraint on creativity. For Eastern bloc intellectuals, the rigidly structured labyrinth of choices offered by the government seemed overly restrictive. Some chose to

29 Dmitrii Pospelov and Veniamin Pushkin, *Myshlenie i avtomaty* (Thinking and automata) (Moscow: Sovetskoe radio, 1972), 140–141 (emphasis added).

30 Ibid., 139.

31 For a historical overview, see Dmitrii Pospelov, *Situatsionnoe upravlenie: teoriia i praktika* (Situational control: theory and practice) (Moscow: Nauka, 1986), 254–58.

emigrate. Some, like Pospelov and Pushkin, chose to expose the limitations of choice-driven behaviour and to create new problem spaces.

An intellectual under an oppressive regime: striving for autonomy

Soviet intellectuals developed sophisticated strategies for living under surveillance. Recent studies of Soviet intelligentsia undermine the Cold War stereotypes of the Soviet scientist as either blindly supporting or passively resisting government policies.[32] A more typical figure would be a physicist working on nuclear weapons during the day, and reading underground literature at night.[33] Interested in results, the government allowed the scientists some intellectual license, as long as it was limited to their subject of study. The historian David Holloway called nuclear weapons laboratories 'islands of intellectual autonomy'.[34] One theoretical physicist later recalled:

> Physicists constituted a privileged caste, an aristocracy. There were fewer controls on our freedom than on those of any other member of Soviet civil[ian] society. The only laws we felt restricted by were those relating to the conventions of scientific work. Relatively speaking, we were free people.[35]

Mathematicians and computer specialists working on defence projects enjoyed a similar privileged status. As priests in a temple of the all-powerful goddess, the Computing Machine, they created their own dominions of intellectual autonomy in the climate-controlled, limited-access rooms housing mammoth-size computers of the first generation. The mathematicians Izrail Gelfand and Mikhail Tsetlin, of the defence-research-oriented Institute of Applied Mathematics, used

32 See *Osiris* vol. 23: *Intelligentsia Science: The Russian Century, 1860–1960*, ed. Michael D. Gordin, Karl Hall and Alexei Kojevnikov (2008).
33 Stanislav Rassadin, *Kniga proshchanii* (A book of farewells) (Moscow: Tekst, 2004), 217.
34 David Holloway, 'Physics, the State, and Civil Society in the Soviet Union', *Historical Studies in Physical and Biological Sciences* 30, no. 1 (1999): 175.
35 Mark Azbel, quoted in ibid., 187.

their portion of intellectual freedom to engage in a study of the central nervous system.

In 1958, Gelfand and Tsetlin organized an informal regular seminar on mathematical models in physiology.[36] Neurophysiologists traditionally assumed that various nodes within the central nervous system coordinated their activity via a complex system of interconnections. This assumption, however, baffled mathematicians: in a large system, the number of connections would grow so rapidly that any mathematical model would become too complex. Tsetlin and Gelfand, by contrast, proposed a model in which every node regarded the activity of all the other nodes as changes in its environment. They showed that individual nodes did not have to interact directly but could merely observe changes in their environment and follow a simple adaptive algorithm, minimizing their interactions with the environment. This resulted in purposeful behaviour of the system as a whole, if one defined purpose as minimization of the system's interaction with its environment. In this model, purposeful behaviour of the whole system did not require great complexity from its subsystems. All individual parts acted very simply: they tried to avoid interaction, rather than to build complex coordination networks. Gelfand and Tsetlin called this adaptive mechanism the 'principle of least interaction':

> At each moment, the subsystem solves its own 'particular', 'personal' problem—namely, it minimizes its interaction with the medium; therefore, the complexity of the subsystem does not depend on the complexity of the entire system. … our mathematical models allow us (to a certain degree) to imagine the interaction of the nerve centers without considering the complex system of links and the coordination of their activity.[37]

36 Viacheslav Vs. Ivanov, 'Iz istorii kibernetiki v SSSR. Ocherk zhizni i deiatel'nosti M.L. Tsetlina' (From the history of cybernetics in the USSR: an outline of life and work of M. L. Tsetlin), in *Ocherki istorii informatiki v Rossii* (Essays on the history of informatics in Russia), ed. Dmitrii A. Pospelov and Iakov I. Fet (Novosibirsk: OIGGM SO RAN, 1998), 568.

37 Mikhail Tsetlin, *Automaton Theory and Modeling of Biological Systems*, trans. Scitran (New York: Academic Press, 1973), 150–52.

The peculiar definition of purposeful behaviour as the minimization of the system's interaction with its environment clearly resonated with the Soviet intelligentsia's drive to preserve maximum intellectual autonomy. Tsetlin argued that his model of the nervous system had the advantage of non-individualized control: there was no need to tell every node in the system what it was supposed to do; the system used its freedom of manoeuvre to self-organize under most general conditions. At a lecture before the Physiological Society in February 1965, Tsetlin explicitly brought up a comparison of free and forced labour to highlight the advantages of self-organization:

> The work of prisoners is more expensive than that of free men, even though the former are much worse fed and clad, and they work no less. The point is not only that the efficiency of prisoners is lower, but that a prisoner must be fed, clad, and watched by someone else. With a free person the matter is different: … my manager … doesn't have to think when to change my shoes or linen or what to do with my children.[38]

The MIT biophysicist Murray Eden once remarked: 'One wonders whether it is a reflection of cultural or social differences that Tsetlin chose to study cooperative phenomena in choosing "expedient" behaviour, while American game theory focuses on competition among the players'.[39] Tsetlin's model, strictly speaking, was not a mathematical implementation of socialist ideals. It reflected the intelligentsia's peculiar position within the Soviet system, in which 'cooperative phenomena' emerged out of individuals' efforts to escape control by the environment (the state) or by other individuals ('people's patrols'). Eden's suggestion of the social and cultural roots of different approaches to game theory, however, is worth exploring in greater detail.

38 Ibid., 125
39 Murray Eden, 'Foreword', ibid., xi.

Individualistic games of capitalism

In 1926, the Hungarian-born American mathematician John von Neumann developed an axiomatic formalization of two-person, zero-sum games with a finite number of 'strategies' (complete plans of the game). It was based on the Western concept of social interaction as a competition between self-interested, rationally calculating, yet cautious opponents.

Von Neumann proved the minimax theorem, asserting the existence of an optimal 'mixed', or randomized, strategy for each player, which would minimize the maximum loss, and would guarantee that each wins the 'value of the game'. He believed that the minimax strategy captured some fundamental aspect of human rationality: 'Any events—given the external conditions and the participants in the situation (provided that the latter are acting of their own free will)—may be regarded as a game of strategy if one looks at the effect it has on the participants'.[40]

Von Neumann's biographer Steve Heims has traced von Neumann's formalism to his perception of the world as filled with ruthless competitors who viewed all the other players as cunning enemies:

> His temperament was conditioned by the harsh political realities of his Hungarian experience. The recommended style of 'playing the economic game', the emphasis on caution, on calculation of expected consequences, the whole utilitarian emphasis aptly expresses the characteristic ideals of the middle class in capitalist societies.[41]

In 1944, von Neumann and his collaborator, the Austrian-born American economist Oskar Morgenstern, expanded the original conceptual framework of game theory to treat problems of economics in their book, *Theory of Games and Economic Behavior*. They explicitly challenged deterministic decision-making enshrined in neoclassical economics and presented the 'solution' of an economic game as a probabilistic

40 Von Neumann (1928), quoted in Robert J. Leonard, 'From Parlor Games to Social Science: Von Neumann, Morgenstern, and the Creation of Game Theory, 1928–1944', *Journal of Economic Literature* 33 (June 1995): 735.

41 Steve J. Heims, *John von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death* (Cambridge, MA: MIT Press, 1980), 296.

'stable set' of possible apportionments of payoff among the players. As the historian Philip Mirowski has argued, they treated mixed strategies as 'a representation of the stochastic nature of thought itself' and effectively turned minimax strategizing into 'the very epitome of the abstract rationality'.[42] Mirowski has further suggested that von Neumann and Morgenstern came to believe that game theory could 'simulate the behavior of any opponent and therefore serve as a general theory of rationality', and that in their writings 'game theory and artificial intelligence tended to blur together'.[43]

Among the indeterminism celebrated by von Neumann and Morgenstern, one thing remained stable throughout: the rules of the game. Fixing the rules of the game not only made it possible to derive powerful formal results in game theory. It also provided an anchor for the notion of rationality: the world was too complex for deterministic analysis, but it still followed rules, so a stochastically equipped mind could still calculate an optimal set of strategies.

American defence analysts asserted that 'the significance of game theory as a decision tool is that it eliminates guessing an opponent's intentions'.[44] While guessing seemed the opposite of rational problem-solving to American analysts, it was often the only option available to an intelligent decision-maker in the Soviet Union.

Collective games of socialism

Scholars studying Soviet science in the late Stalinist and Khrushchev periods have remarked on the ritualistic patterns of behaviour in the scientific community. Whether scientists were engaged in public discussions of the philosophical and ideological meaning of their discipline, or tried to jump on the bandwagon of a fashionable intellectual trend, they had to play a game according to the unspoken rules of the

42 Philip Mirowski, 'When Games Grow Deadly Serious: The Influence of the Military on the Evolution of Game Theory', in *Economics and National Security*, supplement to *History of Political Economy* 23, ed. Craufurd Goodwin, (Durham, NC: Duke University Press, 1991), 237.

43 Philip Mirowski, 'What Were von Neumann and Morgenstern Trying to Accomplish?' in *Towards a History of Game Theory*, supplement to *History of Political Economy* 24, ed. E. Roy Weintraub (Durham, NC: Duke University Press, 1992), 125, 127.

44 Quoted in Mirowski, 'When Games Grow', 251.

public behaviour of a Soviet scientist.[45] Ritual critique of ideological enemies, skilful manipulation with suitable quotes from Marx or Lenin, and ingenious translation of scientific terminology into an ideology-laden language, were among the indispensable strategies of Soviet science. The outcome of debates over the validity of scientific theories often depended on the discussants' abilities to play the game.

The play was complicated by the uncertainty over the rewards and punishment for specific strategies. Frequent swings in the direction of Stalinist ideological campaigns often left slow thinkers stuck with old, outdated slogans and made them vulnerable to attack. Those scientists who could not properly decipher 'signals' from above were often perplexed about the rules and direction of the most recent campaign.

The fundamental uncertainties of Soviet social games were reflected in Mikhail Tsetlin's theory of collective games of automata. An automaton is a mathematical model of a finite state machine that changes its state according to its transition diagram and the current input. Tsetlin interpreted an automaton as an agent acting in an environment that randomly penalized or rewarded specific behaviours. Unlike the classic von-Neumann-type games, Tsetlin studied games in which the automata faced a world filled with uncertainty. He wrote:

> It should be noted that the automaton games are discussed here from a viewpoint that differs from the one accepted in game theory. Indeed, it is normally assumed in the latter that the game is defined by a system of pay-off functions previously known to the players. … We thought it interesting to consider games played by finite automata having no a priori information about the game, and being forced to shape their strategies for each successive replay in the course of the game itself.[46]

In Tsetlin's games, 'the players have practically no information about the game. They are ignorant of the number of other players involved, of the situation at any particular moment and even of what kind of game

45 Alexei Kojevnikov, 'Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy circa 1948', *The Russian Review* 57 (January 1998): 25—52; Nikolai Krementsov, *Stalinist Science* (Princeton: Princeton University Press, 1997), esp. 239–48; and Gerovitch, *From Newspeak to Cyberspeak*.
46 Tsetlin, *Automaton Theory*, 6.

they are actually playing'.[47] Tsetlin informally compared his model of an agent operating in an environment with unknown and changing rules to a 'little animal in the big world'.[48] His friend, cybernetic neurophysiologist Nicholas Bernstein, used a similar metaphor to describe the fundamental uncertainties of intellectual activity: 'To use a metaphor, we might say that the organism is constantly playing a game with its environment, a game where the rules are not defined and the moves planned by the opponent are not known'.[49]

Tsetlin discovered that in a changing environment in which the probabilities of penalties and rewards varied over time, the most successful were the automata that did not have too many states. In other words, if the rules of the game constantly changed, it was not a good idea for the automaton to remember too much of its own history. The more dynamic the environment, the shorter was the optimal depth of the automaton's 'memory'.

In his study of collective 'distribution games', Tsetlin presented a thinly veiled commentary on the economic strategies of individuals under socialism. First, he considered a game in which a group of automata competed for resources (rewards or payoffs) by choosing different strategies. He designed automata that were completely unaware of the relative strengths of different strategies, but would eventually settle on the optimal strategy by reacting to rewards from their environment. Tsetlin showed, however, that their average gain could be increased if the automata played a game-theory version of socialism; a game with a 'common fund', in which all gains and losses of individual automata were summed up and then shared equally among them. The drawback was that the common fund camouflaged the link between individual contribution and reward and thus placed greater demands on the memory capacity of individual automata. One could 'reap the benefits of a common fund procedure starting from a certain level of complexity' of automata memory, he concluded, 'if the memory capacity is below this threshold, the introduction of a common fund reduces the average gain'.[50]

47 Viktor Varshavskii and Dmitrii Pospelov, *Puppets Without Strings*, trans. A. Kandaurov (Moscow: Mir, 1988), 97.
48 Tsetlin, *Automaton Theory*, 132.
49 Nicholas Bernstein, *The Co-ordination and Regulation of Movements* (Oxford: Pergamon Press, 1967), 173.
50 Varshavskii and Pospelov, *Puppets Without Strings*, 100.

In informal discussions, Tsetlin mockingly translated this rule into the clichéd parlance of the Soviet ideological discourse as 'the negative effect of [wage-]levelling and inadequate consciousness [of workers]'.[51] Indeed, the Soviet press often blamed the low quality of consumer products on workers' 'low level of consciousness'. Soviet propaganda routinely called on the workers to raise their consciousness and to work harder for a common fund. Tsetlin provided a mathematical formalization of this ideological dogma, calculating the precise memory capacity ('consciousness level') needed to find an optimal strategy in a game with a common fund.

Tsetlin's colleagues turned his result into a fundamental principle of human thinking and behaviour. Viktor Varshavskii and Dmitrii Pospelov interpreted memory capacity as a general measure of intellectual ability.[52] They correlated one's 'intellectual level' with the ability to find an optimal strategy in a game in which gains and losses were not explicitly tied to one's immediate actions but were produced at a higher level of organization. They concluded that 'capitalism is more profitable when the management system is simple and socialism is more profitable when the management system is elaborate'.[53] The writings of Soviet AI specialists paradoxically combined a thinly veiled critique of socialist redistribution and a peculiar definition of intellect as the ability to find an optimal strategy of living under socialism.

The notion of a game with unknown or changing rules was very familiar to the liberal intelligentsia. They played a cat-and-mouse game with the Soviet government, constantly challenging the fuzzy boundaries of permissible discourse. While Soviet laws ostensibly proclaimed many democratic freedoms, the actual practice was to suppress any significant dissent by placing it under the vague rubric of 'anti-Soviet activity'. Engaging in an open political protest would mean violating the most expedient strategy of behaviour under socialism: to minimize one's interactions with the political environment. Entering in a direct confrontation with the authorities was a flagrant violation of the 'principle of least interaction'.[54]

51 Ibid., 101.
52 Ibid., chap. 3.
53 Ibid., 102.
54 Evgenii L. Feinberg, 'Dlia budushchego istorika' (For a future historian), in *On mezhdu nami zhil: Vospominaniia o Sakharove* (He lived among us: memoirs about Sakharov), ed. Boris L. Altshuler et al. (Moscow: Praktika, 1996), 679.

Two central metaphors of AI: rats vs butterflies

Two metaphors capture crucial differences in the cultural stereotypes of thought and behaviour reflected in AI systems implemented in the Soviet Union and the United States. Life as a maze—a labyrinth in which we must find the right path—became the central metaphor for American AI. The metaphor of a labyrinth evoked the behaviourist pattern of B.F. Skinner's experiments on rats running T-shaped mazes and the popular American cultural image of the 'rat race'. In 1950 Claude Shannon designed a mechanical mouse that navigated a labyrinth in search of a metal 'cheese'. Herbert Simon's study of administrative behaviour, in turn, took rats running mazes as a paradigmatic case: 'A simplified model of human decision-making is provided by the behaviour of a white rat when he is confronted, in the psychological laboratory, with a maze, one path of which leads to food'.[55] Simon insisted that the limited knowledge and intellectual capacities of a rat better reflected the constraints on human rationality than the assumption of divine omniscience and perfect rationality: 'We need a less God-like and more rat-like chooser'.[56]

For Soviet AI specialists, the central metaphor for decision-making was not the search in a fixed labyrinth, but the flight of a butterfly, charting its flight trajectory through random streams of air. Viktor Varshavskii and Dmitrii Pospelov described a system that simulated the behaviour of a moth hunted by a bat. When the bat was too close and the moth could not fly away, the moth started dashing around in a chaotic flight:

> The chaotic flight is a series of passive falls with folded wings, sharp turns, loops and dives. In other words, the moth follows a trajectory which makes it more difficult for the bat to predict its location from one moment to the next. We should mention that in experiments the chaotic flight strategy saved the moth's life 70 percent of the time.[57]

55 Simon (1945), quoted in Crowther-Heyck, *Herbert A. Simon*, 112.
56 Simon (1954), quoted ibid., 6.
57 Varshavskii and Pospelov, *Puppets Without Strings*, 77.

A butterfly fluttering in a chaotic current of life and trying to escape a predator—this image was all too familiar to Soviet scientists, trying to preserve their intellectual autonomy.

American and Soviet AI specialists were seeking out general principles: universal, timeless mechanisms of thinking and behaviour. Their generalizations, however, were based on culturally conditioned cases. The examples that American and Soviet scientists had at their disposal, were, in fact, culturally specific patterns of social organization and decision-making. When trying to grasp universality, AI models manifested just the opposite: the specificity of cultural patterns.

Without knowing it, science often speaks with a national accent. Cultural symbolic systems can manifest themselves in scientific ideas as clearly as in literature or art. In their simulations of human thinking, AI systems truly reflect both mechanisms of reason and patterns of irrationality, individual creativity and social stereotyping, human nature and human culture.

Note

This article is a shortened and revised version of Slava Gerovitch, 'Artificial Intelligence with a National Face: American and Soviet Cultural Metaphors for Thought', in *The Search for a Theory of Cognition: Early Mechanisms and New Ideas*, ed. Stefano Franchi and Francesco Bianchini (Amsterdam: Rodopi, 2011), 173–194.

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