Computational Approaches to Strategy 1.0

Adam Elkus

November 3, 2015

Abstract

Many disciplines have found a computational approach useful for their exploration of complex and ill-structured questions and domains. Could strategic theory benefit from computational methods? This paper lays out some puzzles and questions in military strategy relating to the "black box" of how strategies are produced and the function they serve as complex knowledge structures and then provisionally discusses how and why computational methods are appropriate for making progress in strategic research.

1 Introduction

1.1 Preamble/Release Notes/Disclaimer

Please cite this paper if it is of use to your work. This paper represents the endpoint (for now, some key literature relevant to it will only be released next year) of a long process of conceptual brainstorming as to how computational methods in the social, behavioral, and computer sciences can aid in the process of strategic theory development. it was, a month ago, a 30-page outline. Now it is.....slightly less than 30 pages! As a student of security and strategy that has transitioned to a dramatically different (in theory and method), PhD program in Computational Social Science, I wrote this principally for myself as the methodological primer I never had about how and why my area of substantive research interest and my area of methodological interest fit together.

Hence it is full of spelling mistakes, has ad hoc citations, displays bad grammar and sentence structure, etc. And it was written in between other assignments and projects. That said, it had to be written just simply to give me a sense of purpose and direction in what I am doing, and to ensure that the methods fit the research questions instead of vice versa (as so often was the case in the Cold War use of computer models and simulations in strategy). It is my intention that this document serve as a reference point for me about how this is all supposed to work out. If it is useful to you, then I am pleased to be able to help.

As indicated by the 1.0 marker, I will revise this (first for spelling/grammar issues, later on for content) progressively over time. But unlike my past attempts

at laying out my research program, I think that the core elements of this will remain reasonably stable over time. This document represents a particular endpoint of a very long journey that began when I was first a PhD student in international relations. It is, of course, only a single data point in that overall journey, hence I will try to remain humble about how much I will want to keep or revise beyond the bare minimum elements as time goes on. Many people played a key role in helping me, mostly just by showing interest, giving me a space to develop the ideas, showing that they were, at a minimum, interested in the themes in the document, or otherwise giving me advice or basic feedback on how to develop this.

I am eternally indebted to various people who gave me useful feedback on this and variants of it over time, but in specific I will thank Aaron Frank, Robert Axtell, William Kennedy, T. Greer, C. Christine Fair, David Maxwell, Daveed Gartenstein-Ross, Nick Prime, A.E. Stahl and William F. Owen, Lawrence Freedman, Joanna Bryson, Michael Horowitz, David Betz, Tom Wein, Rex Brynen, David Masad, Russell Thomas, Joshua Foust, Dan "Tdaxp", David Auerbach, Brett Fujioka, Jay Ulfelder, Lukas Milevski, Kenneth Payne, L.C Rees, "Pusha C#", Robert Mehlinger, Aaron Mannes, Phillip Arena, David Blair, Stephanie Carvin, W.K Winecoff, Anton Strezhnev, Samuel Liles, Rich Ganske, Daniel Nexon, Patrick Thaddeus Jackson, Jason Fritz, Richard Andres, Ryan Evans, P.W. Singer, Rei Tang, Nathan Finney and the rest of the *Strategy Bridge* crew, Ben Denison, Torie Bosch, Mark Safranski, Graham Peterson, Natalie Sambhi, Bill French, Stephen Glinert, Olivier Schmitt, Sean Lawson, Tim Stevens, Jack McDonald, Shane Deichman, Paul T. Mitchell, Benjamin Armstrong, Thomas Rid, Brandon Valeriano, Nils Gilman, Bob Gourley, Costa Samaras, Robert Morgus, Daniel Bilar, John Robb, Charles Cameron, Miles Brundage, Patrick Tucker, Mark Mateski, and countless others that I will likely add as playing a helpful role in some shape or form in the creation of this document, whether in terms of direct comments or simply just basic interest in the ideas that went into it and previous iterations or a willingness to listen to me stumble through the process and offer helpful advice when necessary.

And of course I think my wife who found these ramblings about strategy so attractive in the first place when I met her in 2011. I am not going to exaggerate in saying that she is mostly how I keep moving despite all of the difficulties of what I am trying to do.

1.2 Computational approaches to strategy

Computational methods in strategic theory are rare. Computation has been seen in wargaming, operations research, and similar activities that support strategy. But strategic theory itself remains mostly studied with verbal theory and case studies. This is not without good reason: the phenomena of study is highly stochastic, interactive in the complex organization of its components, and deals with things that are difficult to formalize and quantify.[1] Moreover, many of

[1] McMaster, H. R. "The Uncertainties of Strategy." *Survival* 57.1 (2015): 197-208.

the attempts to utilize computer models, simulations, and other broadly quantitative and formal approaches have proved underwhelming in practice.[2] Many practitioners and researchers believe that the choice quite literally is between Clausewitz and computer, identifying computational methods with technological hubris and fallacies of the rational perfection of war.[3] Finally, computer or not, practitioners and researchers have also come to distrust (not without justification), standard research techniques and assumptions in modern social science, arguing that it is overly reductionist and avoids the task of explaining the instrumental linkage between strategic goals and coercive behaviors .[4] All of these criticisms, to some degree, hit home. But they are also not new. They have been a part of strategic theory and security studies' self-justification for some time. [5]

However, the key question is whether this methodological monoculture serves the central goal that Bernard Brodie laid out after World War II: developing a multi-disciplinary descriptive theory of how force is used to achieve political aims that might also serve as a practical art to be studied by practitioners and interested persons civilian and military alike.[6] Can other methods of study, argumentation, and research be fruitfully used to analyze core questions of strategic theory and behavior that stem from the focus on how political communities utilize coercive force to achieve their desired ends? [7] It is my argument, which I hope to convince you of in this document, that the answer to the latter question is "yes." Computational approaches to strategic theory will never overtake the dominant methods in the discipline, nor should they. However, despite the checkered history of defense analysis and simulation as "technowar," they deserve a second look from researchers in the field.[8] Why?

In the 1960s, Herbert Simon coined the term "sciences of the artificial" to describe the study of both human-made objects and systems (governments, economies, engineered artifacts, etc) and the use of computers to investigate and simulate biological systems and properties.[9] Strategy is very much a form of

[2]McMaster, H. R. "The human element: When gadgetry becomes strategy." *World Affairs* (2009): 31-43, McMaster, H. R. "Learning from contemporary conflicts to prepare for future war." *Orbis* 52.4 (2008): 564-584, McMaster, H.R. "On war: lessons to be learned." *Survival* 50.1 (2008): 19-30.

[3]Murray, Williamson. "Clausewitz out, computer in: military culture and technological hubris." *The National Interest* (1997): 57-64.

[4]Watts, Barry D. "Ignoring reality: Problems of theory and evidence in security studies." *Security Studies* 7.2 (1997): 115-171.

[5]Gray, Colin S. *Strategy and defence planning: meeting the challenge of uncertainty*. Oxford University Press, 2014, Betts, Richard K. "Should strategic studies survive?." *World Politics* 50.01 (1997): 7-33, Walt, Stephen M. "Rigor or rigor mortis? Rational choice and security studies." *International Security* 23.4 (1999): 5-48, Finney, Nathan K. "On Strategy." *Parameters* 45.1 (2015): 137, McMaster, H. R. "The Uncertainties of Strategy." *Survival* 57.1 (2015): 197-208.

[6]Brodie, Bernard. "Strategy as a Science." *World Politics* 1.04 (1949): 467-488, Brodie, Bernard. "Strategy as an Art and a Science." *Naval War College Review* 51.1 (1998): 26.

[7]Betts, Richard K. "Should strategic studies survive?." *World Politics* 50.01 (1997): 7-33.

[8]Gibson, James William. *The perfect war: Technowar in Vietnam*. Atlantic Monthly Press, 2000.

[9]Simon, Herbert A. *The sciences of the artificial*. MIT press, 1996, Klahr, David, and

phenomena in the Simon mode. It is human-constructed, and is a means of dealing with the violent outgrowth of political issues arising from both engineered and natural phenomena.[10] Yet it is also a knowledge structure for organizing and directing internally stored world knowledge, analogies, reasoning processes, and relationships.[11] If Simon and others saw their work as the sciences of the artificial, it follows that the computational analysis of strategy concerns the strategies of the artificial.

In specific, I argue that computational approaches to strategy can help by focusing on the manner in which the "interior world" of strategy is often treated as a black box. Strategic researchers generally focus on tangible and observable elements, potentially missing complex and useful generative mechanisms that computational tools could – like a microscope or telescope – illuminate and render legible. Whether as a simulation model or a data mining algorithm, these computational instruments can serve as aids to theory development in a way that complements existing approaches in both research question and theoretical concern. This paper will seek to validate this claim through an detailed analysis of the potentially fruitful applications to computational methods to strategic theory.

1.3 Plan of the paper

I argue that computational approaches to strategy can help by focusing on the manner in which the "interior world" of strategy is often treated as a black box. Strategic researchers generally focus on tangible and observable elements, potentially missing complex and useful generative mechanisms that computational tools could – like a microscope or telescope – illuminate and render legible. Whether as a simulation model or a data mining algorithm, these computational instruments can serve as aids to theory development in a way that complements existing approaches in both research question and theoretical concern. I provide support for this claim as follows.

In the first section, *The Black Box of Strategy*, I establish the basic grounds for my argument. First, I define strategy, relate what it is and what it is not, and list some common criticisms and controversies in the discipline. This is, however, just an intro to my larger point. I explain how American strategy converged to a particular understanding of a boundedly rational, procedural decisionmaker due to the challenges of Cold War conflict, giving John Boyd and Andrew Marshall as representative examples. Next, I show how a concern with breaking the aformentioned "black box" flows out of such an analytical tradition, and how recent work in strategic research reflects this.

Kenneth Kotovsky, eds. *Complex information processing: The impact of Herbert A. Simon.* Psychology Press, 2013, Simon, Herbert A. "Cognitive science: The newest science of the artificial*." *Cognitive scienc*e 4.1 (1980): 33-46, Meng, Jude Chua Soo. "Donald Schn, Herbert Simon and the sciences of the artificial." *Design Studies* 30.1 (2009): 60-68.

[10] Frank, Aaron Benjamin, et al. "Dealing with femtorisks in international relations." *Proceedings of the National Academy of Sciences* 111.49 (2014): 17356-17362.

[11] Gordon, Andrew S. *Strategy representation: An analysis of planning knowledge.* Taylor & Francis, 2004.

In the second section, *Strategy: A Computational Approach*, I explain how computation can help. First, I examine some research questions and possible directions for research that flow from a desire to break the black box, and why it may not be useful to examine such problems solely from the perspective of verbal theory and qualitative case studies. Next, I examine two carciatures of what is a vibrant and diverse set of methods in computational science, explaining their nature, dynamics, and how they are utilized. Finally, I conclude with a speculative frame story about how both could be utilized to contribute to questions of relevance to strategic theory.

1.4 TODO

I find the section "the challenge of breaking the black box" to be too vague, mystical-sounding, and weak. I will likely try to get rid of confusing, overlapping, contradictory, and redundant terminology in whatever next iteration of this document occurs next. Otherwise, I'm pretty happy with this given the expectations that I had for it.

2 The Black Box of Strategy

2.1 What is strategy?

The study of strategy concerns the use of military (and other, but principally military) power to achieve political objectives. It is a bridge between desired conditions and coercive behavior necessary to realize those conditions. Strategy concerns the interrelationship between people and politics, preparation for conflict, and the conduct of conflict itself. It is, in short, a theory of action – of how actors seek to realize their objectives. [12] Another way to look at strategy is through the relationship of six components: how actors achieve desired ends, interdependent decision-making as a causal factor, the choices available to actors and their subsequent decisions, the role of value systems and preferences, the assumption of some form of rational behavior, and commitment to a descriptive rather than normative explanation of adversarial behavior. [13] Since this is awfully broad, it may be helpful to explain what strategy is not.

Decision-making and algorithms and rules for decision-making is certainly a subset of strategy, but to identify this with strategy makes the category error of neglecting the ways in which strategy is also about the strategist's quest to change the context in which decision-making occurs. [14] Strategy is not security, which is simply a threat to welfare (which can be anything from a bomb to a natural disaster). Nor is strategy the study of strategic culture, as

[12] Baylis, John, James J. Wirtz, and Colin S. Gray. *Strategy in the contemporary world.* Oxford University Press, 2013.

[13] Smith, M.L.R. and Stone, John, Explaining Strategic Theory, *Infinity Journal,* Issue No. 4, Fall 2011, pages 27-30.

[14] Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age.* Routledge, 2004.

culture is relevant to strategy only in terms of how it influences the instrumental process of using coercive behavior to accomplish desired objectives. Strategy is also not just the study of military power, though many self-identified strategic theorists study the application of force. Ideas about strategy derive from and have influenced disciplines outside those concerned with force and the military. Strategy may use ideas from game theory but game theory is a subset of strategy. Additionally, strategy does not merely concern how states use military power in interstate conflict and competition; it concerns much broader dynamics. [15]

Finally, strategy is not a single discipline but rather may be regarded as a meeting point for many different disciplines. [16] While their proviso about scientific understanding ought to be regarded as more variable than asserted, Smith and Stone's description suitably descibes the intellectual terrain of strategy[17]:

> Before proceeding it is necessary to appreciate how the term theory is being used in this context. Plainly, in any study of the infinitely varied scale of human conduct, Strategic Theory cannot aspire to achieve any hard scientific understanding that survives experimental testing under exactly replicable conditions. However, it does constitute a theory, in the broader sense, which advances a set of propositions that, if true, can be held to explain certain facts or phenomena. In this regard, Strategic Theory reveals itself less as a set of hard and fast rules, and more as a series of purposive assumptions, or rules of understanding, that guide analysis; though as we shall endeavour to suggest in the conclusion, these rules do ultimately enable us to posit a plausible, all encompassing, definition of Strategic Theory.

Further differentiating strategy from other related fields is the unique utility of strategy as a mode of explanation. Existing social science approaches to analyzing strategic phenomena neglect a set of causal factors that stand as intervening variables and/or mechanisms inherent in the explanation of conflict. They underspecify the process of how actors achieve their aims, making it difficult to analyze the process, formulate and test theories, or properly utilize empirical evidence.[18] or ignore it altogether.[19]

As an applied field, strategic theory has an unenviable explanatory challenge. It describes the ways in which actors seek to achieve their aims, but strategic

[15] Smith, M.L.R. and Stone, John, Explaining Strategic Theory, *Infinity Journal*, Issue No. 4, Fall 2011, pages 27-30.

[16] Baylis, John, James J. Wirtz, and Colin S. Gray. *Strategy in the contemporary world.* Oxford University Press, 2013.

[17] Smith, M.L.R. and Stone, John, Explaining Strategic Theory, *Infinity Journal*, Issue No. 4, Fall 2011, pages 27-30.

[18] Watts, Barry D. "Ignoring reality: Problems of theory and evidence in security studies." *Security Studies* 7.2 (1997): 115-171, Thagard, Paul. "Adversarial problem solving: Modeling an opponent using explanatory coherence." *Cognitive Science* 16.1 (1992): 123-149, and Kott, Alexander, and William M. McEneaney, eds. *Adversarial reasoning: computational approaches to reading the opponents mind.* CRC Press, 2006

[19] Betts, Richard K. "Should strategic studies survive?." *World Politics* 50.01 (1997): 7-33.

knowledge itself is necessarily a part of how actors achieve their aims. If all models are maps of a hitherto unknown territory, strategic theory is a map that contains a map. Nonetheless, the field has experienced substantial criticism for basic issues of theory and method.

The first criticism lies in the field's commitment to rationalism, rooted in the view of actors as deterministically pursuing desired ends through ways and means. [20] A related criticism is that varieties of strategy exist, and that the rationalist perspective unnecessarily privileges one view of strategic reasoning. [21] Another perennial criticism is that strategy also has lost sight of the basic challenge of translating political aims into military behavior.[22] Strategy has also been criticized from the perspective of strategic culture, arguing that traditional conceptions of strategy are ethnocentric and lack ecological validity. [23] Another biting criticism is that the field is committed to a top-down conception of strategy as rational design that does not acknowledge the complexities of how strategy is made in the real world. [24] Finally, others have suggested that the discipline lacks rigor and has never found a proper institutional home.[25] Of course, such criticism merely raises the question of what strategy is to begin with. Leading textbooks in the field acknowledge that the scope of what the field has considered has grown and is at best uncertain. [26]

2.2 Strategic theory and the Cold War legacy

In the United States, strategic studies has been profoundly influenced by the Cold War necessity for management of complex sociotechnical systems. [27]

[20] See, for example, Bull, Hedley. "Strategic Studies and Its Critics." *World Politics* 20.04 (1968): 593-605, Freedman, Lawrence. *Strategy: a history*. Oxford University Press, 2013, Payne, Kenneth. *The psychology of strategy*. Oxford University Press, 2015, and Betts, Richard K. "Is strategy an illusion?." *International Security* 25.2 (2000): 5-50.

[21] Paparone, Chris. *The sociology of military science: prospects for postinstitutional military design*. A&C Black, 2012 and Freedman, Lawrence. *Strategy: a history*. Oxford University Press, 2013.

[22] Heuser, Beatrice. *The evolution of strategy: thinking war from antiquity to the present*. Cambridge University Press, 2010, Strachan, Hew. *The Direction of War: Contemporary Strategy in Historical Perspective*. Cambridge University Press, 2013, and Marshall, Andrew W. "Strategy as a Profession for Future Generations." *On Not Confusing Ourselves: Essays on National Security Strategy in Honor of Albert and Roberta Wohlstetter. Westview Press*, 1991: 302-311.

[23] Johnston, Alastair Iain. "Thinking about strategic culture." *International security* (1995): 32-64, Booth, Ken. *Strategy and Ethnocentrism (Routledge Revivals)*. Routledge, 2014 and Gray, Colin S. "Strategic culture as context: the first generation of theory strikes back." *Review of international studies* 25.01 (1999): 49-69.

[24] Popescu, Ionut C. Design and Emergence in the Making of American Grand Strategy. Diss. Duke University, 2013.

[25] Freedman, Lawrence. "Does Strategic Studies have a Future?." *Strategy in the Contemporary World*: 391-409.

[26] Baylis, John, James J. Wirtz, and Colin S. Gray. *Strategy in the contemporary world*. Oxford University Press, 2013.

[27] For a definition of sociotechnical systems, see Fox, William M. "Sociotechnical system principles and guidelines: past and present." *The Journal of Applied Behavioral Science* 31.1 (1995): 91-105.

Strategic studies, in other words, is a product of the same sea change in academic investment that has been seen in many of the other sciences.[28] Certainly this can and should be viewed as a small component of a larger sea change in the Western sciences toward a "machine" view of the natural world and human conflict writ large. [29] This entails a view of science as the study of hierarchy and process in procedural, adaptive, and constrained organisms embedded in complex environments.[30] This also suggested an interest in the procedural rationality of a constrained and adaptive problem-solver defined most basically in terms of representation and search. [31] However, in the United States, we can see in the figures of John Boyd and Andrew Marshall two differing views on what is important in strategy that stem from this basic premise.

Andrew Marshall particular took a view of the problem of strategic thought rooted in the issue of understanding, qualitatively, how the dynamic interaction between two adversaries could be understood and compared. A favorite example of Marshall's about the fallacy of traditional strategic analysis was the way in which planners systematically ignored the nature in which Soviet strategy was bounded by interorganizational disputes and other constraints.[32] The similarity to "bounded rationality" in social science and psychology was no accident – Marshall was profoundly inspired by the ideas of Herbert Simon and other Cold War social and behavioral scientists. [33]

[28]Edwards, Paul N. *The closed world: Computers and the politics of discourse in Cold War America*. MIT Press, 1997, Mirowski, Philip. *Machine dreams: Economics becomes a cyborg science.* Cambridge University Press, 2002, Erickson, Paul, et al. *How reason almost lost its mind: The strange career of Cold War rationality.* University of Chicago Press, 2013, Thomas Rid forthcoming 2016, Cohen-Cole, Jamie. *The open mind: Cold War politics and the sciences of human nature.* University of Chicago Press, 2014, Amadae, Sonja Michelle, and Sonja Michelle Amadae. *Rationalizing capitalist democracy: The cold war origins of rational choice liberalism.* University of Chicago Press, 2003, Heyck, Hunter. *Age of System: Understanding the Development of Modern Social Science.* JHU Press, 2015, Freedman, Lawrence. "Social Science and the Cold War." Journal of Strategic Studies ahead-of-print (2015): 1-21, McMaster, H. R. "The Uncertainties of Strategy." *Survival* 57.1 (2015): 197-208.

[29]Bousquet, Antoine. *The scientific way of warfare: Order and chaos on the battlefields of modernity.* Cinco Puntos Press, 2009, Dyson, George. *Darwin among the machines: The evolution of global intelligence.* Da Capo Press, 1998, Boden, Margaret Ann. Mind as machine: A history of cognitive science. Oxford University Press, 2006, Ekbia, Hamid Reza. *Artificial dreams: The quest for non-biological intelligence.* Cambridge University Press, 2008, Nilsson, Nils J. *The quest for artificial intelligence.* Cambridge University Press, 2009, Kline, Ronald R. *The Cybernetics Moment: Or Why We Call Our Age the Information Age.* JHU Press, 2015, Hayles, N. Katherine. *How we became posthuman: Virtual bodies in cybernetics, literature, and informatics.* University of Chicago Press, 2008, Johnston, John. *The allure of machinic life: cybernetics, artificial life, and the new AI.* MIT Press, 2008, Stanovich, Keith E. *The robot's rebellion: Finding meaning in the age of Darwin.* University of Chicago Press, 2005.

[30]Simon, Herbert A. *The sciences of the artificial.* MIT Press, 1996, Rosenbloom, Paul S. *On computing: the fourth great scientific domain.* MIT Press, 2012.

[31]Brom, Cyril, and Joanna Bryson. "Action selection for intelligent systems." *European Network for the Advancement of Artificial Cognitive Systems* (2006), Shanker, Stuart G. *Wittgenstein's Remarks on the Foundations of AI.* Routledge, 2002, Downing, Keith L. *Intelligence Emerging: Adaptivity and Search in Evolving Neural Systems.* MIT Press, 2015.

[32]Bracken, Paul. "Net Assessment: A Practical Guide." *Parameters* 36.1 (2006): 90.

[33]Krepnivech, Andrew and Barry D. Watts. *The Last Warrior.* Basic Books, 2015, Augier,

John Boyd's view of strategy was related but had key differences. Boyd began by looking at the familiar topic of Cold War procedural rationality in the form of the "simple" Observe-Orient-Decide-Act (OODA) decision loop. But Boyd, mirroring the focus of philosophers of science on the links between cognitive, social, and intellectual dimensions of change in science, came to see the process of strategy as a process of epistemological challenge and change . [34] Whereas Marshall's interests unsurprisingly tilted toward procedural rationality in strategy, Boyd's views were more oriented around epistemic rationality.[35] Boyd's view of strategy as a nonlinear process of feedback and control owed much to first and second order cybernetics, his interest in emergence and evolving systems complexity theory, and his fascination with epistemology and mental models is congruent with cognitivism. [36]

Marshall's approach is often sadly reduced to simply a program for technological military policy, which – while certainly a Marshallian fixation – is still only one (often misunderstood) part of his multifaceted legacy. [37]Today, the legacy of Marshall's approach to strategy may be seen in the competitive strategies approach to strategic thought and a focus on organizations, innovation, and technology more broadly. [38] Boyd's ideas are cited very much in discussions of the impact of automated decision making on strategy, often erronneously.[39] While the problem of automated decisionmaking is very real (emerging work examines military strategy as processed by an hypothetical computational agent), this work has yet to incorporate the richness of Boyd's theories in ways other observes have.[40] However, the most important thing about both is really what they have in common.

Mie. "Thinking about war and peace: Andrew Marshall and the early development of the intellectual foundations for net assessment." *Comparative Strategy* 32.1 (2013): 1-17., Augier, Mie, and David J. Teece. "Understanding complex organization: the role of know-how, internal structure, and human behavior in the evolution of capabilities." *Industrial and Corporate Change* 15.2 (2006): 395-416,

[34]Osinga, Frans. "GettingA Discourse on Winning and Losing: A Primer on Boyd's Theory of Intellectual Evolution." *Contemporary Security Policy* 34.3 (2013): 603-624, Kuhn, Thomas S. *The structure of scientific revolutions*. University of Chicago press, 2012, Thagard, Paul. *Computational philosophy of science*. MIT press, 1993.

[35]Foley, Richard. *The theory of epistemic rationality*. Cambridge, MA: Harvard University Press, 1987.

[36]Osinga, Frans PB. *Science, strategy and war: The strategic theory of John Boyd*. Routledge, 2007.

[37]Rosen, Stephen Peter. "The Impact of the Office of Net Assessment on the American Military in the Matter of the Revolution in Military Affairs." *The Journal of Strategic Studies* 33.4 (2010): 469-482.

[38]Mahnken, Thomas G. "The Future of Strategic Studies." *The Journal of Strategic Studies* 26.1 (2003): x-xviii, Mahnken, Thomas, ed. *Competitive strategies for the 21st century: theory, history, and practice*. Stanford University Press, 2012.

[39]Adams, Thomas K. "Future warfare and the decline of human decisionmaking." *Parameters* 31.4 (2001): 57-71, Marra, William, and Sonia McNeil. "Understanding'The Loop': Regulating the Next Generation of War Machines." *Harvard Journal of Law and Public Policy* 36.3 (2013).

[40]See Payne forthcoming 2015, Payne forthcoming 2016, Rumelt, Richard P. *Inertia and transformation*. Springer US, 1995, Bousquet, Antoine. "Chaoplexic warfare or the future of military organization." *International Affairs* 84.5 (2008): 915-929.

2.3 Strategy's black box

What both Marshall and Boyd had in common was an interest in what might be dubbed a "cognitivist" approach to strategy (I say cognitivist due to shared interest in, at a minimum, ideas from 1950s-60s cognitivism). Both approaches would set the stage for a different, more psychological and behavioral view of strategy. In other words, Marshall and Boyd, despite their intellectual differences, were very similar in that they wanted to peer inside the "black box" of strategic behavior. Whether in terms of Marshall's interested in bounded organizational heuristics and choice or Boyd's fascination with adaptation, mental models, and epistemology, both were highly interested in the background to the production of strategy rather than necessarily the tangible and observable elements of strategy.

One core reason why approaches to the "black box" of strategy have been so few is that it is very difficult to look at anything but what has already been observed utilizing traditional methods of verbal theory and historical analysis. This, despite the schism between strategic studies and game theory/rational choice, relies on what is essentially a revealed preference approach without formal models or statistics. Through detailed study of cases, the analyst can infer a policy preference and analyze how the actor perceived the choices available. This runs into several obvious problems. First, it is easy to simply rationalize any kind of belief or procedure post-hoc through a mangled reading of what will inevitably always be complex and difficult to interpret history.[41] Second, Carl von Clausewitz's own injunction for the theorist to pay attention to the psychological and moral conditions of the battlefield is ignored. [42] Finally, preferences are both revealed by behavior *and* constructed by them. [43]

Certainly this interest in looking at procedural behavior and its complex origins is not new or exclusive to Marshall and Boyd. Sun Tzu, Niccolo Machiavelli, Carl von Clausewitz, and others all discussed psychology, emotion, and other mentalistic attributes of strategy and political contestation at length. And, more specifically, Cold War strategic thinkers concerned with intelligence, decision-making, and strategic surprise discussed perception, information-processing, and other elements of cognition and control at length. [44] One may also see the tradition that Thomas Schelling created with *Strategy of conflict* and *Arms and influence* as embodying a kind of folk psychology with varying degrees of

[41] On this, see Elkus, Adam, Beyond Strategy as a Means to an End, *Infinity Journal*, Vol. 3, Issue No. 4, winter 2014, pages 11-15.

[42] Caraccilo, Dominic J., and John L. Pothin. "Coup doeil: the commanders intuition in Clausewitzian terms." *Air & Space Power Journal* 2.16 (2000): 2000.

[43] Busemeyer, Jerome R., and Peter D. Bruza. *Quantum models of cognition and decision.* Cambridge University Press, 2012.

[44] Allison, Graham T. "Conceptual models and the Cuban missile crisis." *American political science review* 63.03 (1969): 689-718, Cohen, Eliot A., and John Gooch. *Military misfortunes: The anatomy of failure in war.* Simon and Schuster, 2006, Wohlstetter, Roberta. *Pearl Harbor: warning and decision.* Stanford University Press, 1962, Steinbruner, John D. *The cybernetic theory of decision: New dimensions of political analysis.* Princeton University Press, 1974, Jervis, Robert. *Perception and misperception in international politics.* Princeton University Press, 2015.

behavioral realism.[45] However, this program failed to ultimately bear much fruit due in part to fatigue over the "rationality wars" by the late Cold War.[46] It might also be observed that many precepts of these debates have been accepted unconsciously without being critically tested.[47] More broadly, work in foreign policy analysis and political psychology has always incorporated these elements, but strategy is more than just decisionmaking and planning.[48] Emerging work in the study of evolution, ritual, and conflict has also focused on such understandings, but rarely in the context of strategy.[49] There certainly has been useful and interesting work on cognitive computational models of strategy, but much of it is also scattered. [50]

While it is possible to round up myriad literatures to show some penetration in the constituent disciplines and offshoots of strategy, nonetheless it must be concluded that these approaches to the "inner world" of strategy are still very far and few between. Strategy has understandably focused on the problem of how violence may be transmuted into political currency, or the process of erecting a "strategy bridge" between goals and behavior.[51] This certainly has yielded rich insights about the structural challenges and contradictions inherent in such a task. However, the process of how agents cope with such challenges is often treated as a black box, as M.L.R. Smith observes[52]:

> Strategy the consideration of ways, ends and means is an inherently practical subject, concerned as it is with translating aspirations into realizable objectives. The essential feature of strategy, as Colin Gray describes, is that it functions as the bridge between tactics actions on the ground and the broader political effects they are intended

[45] Ayson, Robert. *Thomas Schelling and the nuclear age: strategy as social science*. Routledge, 2004.

[46] Erickson, Paul, et al. *How reason almost lost its mind: The strange career of Cold War rationality*. University of Chicago Press, 2013.

[47] Freedman, Lawrence. "Social Science and the Cold War." *Journal of Strategic Studies* ahead-of-print (2015): 1-21.

[48] Huddy, Leonie, David O. Sears, and Jack S. Levy, eds. *The Oxford handbook of political psychology*. Oxford University Press, 2013.

[49] Norenzayan, Ara. *Big gods: How religion transformed cooperation and conflict*. Princeton University Press, 2013.

[50] Carbonell, Jaime G. "Counterplanning: A strategy-based model of adversary planning in real-world situations." *Artificial Intelligence* 16.3 (1981): 295-329., Bringsjord, Selmer, et al. "Nuclear deterrence and the logic of deliberative mindreading." *Cognitive Systems Research* 28 (2014): 20-43, Kott, Alexander, and William M. McEneaney, eds. *Adversarial reasoning: computational approaches to reading the opponents mind*. CRC Press, 2006., Sukthankar, Gita, et al., eds. *Plan, activity, and intent recognition: Theory and practice*. Newnes, 2014, Gordon, Andrew S. *Strategy representation: An analysis of planning knowledge*. Taylor & Francis, 2004, Tecuci, Gheorghe, et al. "Training and using Disciple agents: A case study in the military center of gravity analysis domain." *AI Magazine* 23.4 (2002): 51, and Lopez Jr, Antonio M., Jerome J. Comello, and William H. Cleckner. "Machines, the Military, and Strategic Thought." *Military Review* 84.5 (2004): 71, Thagard, Paul. "Adversarial problem solving: Modeling an opponent using explanatory coherence." *Cognitive Science* 16.1 (1992): 123-149

[51] Gray, Colin S. *The strategy bridge: theory for practice*. Oxford University Press, 2010.

[52] Smith, M.L.R., Quantum Strategy: The Interior World of War, *Infinity Journal*, Volume 3, Issue No. 1, Winter, 2012, pages 10-13.

> to produce.[i] For this coherently parsimonious reason strategy, in both its operational and academic manifestations, concentrates on practices as physically revealed phenomena. Strategy is, thereby, revealed in clearly observable facts and things, most notably in its association with actions in war. In this regard, strategy, in its application, and in its study, is about palpable acts and outcomes: armed clashes, organized violence, plans, battles, campaigns, victories and defeats.

Of course, this does not necessarily explain how complex observed behaviors are produced in the first place, which was what prompted –in another domain – Simon and other cognitive scientists such as George A. Miller to look inside the agent to explain the origins of cognition and control.[53] Simon and others did so with the concept of bounded rationality in knowledge representation and search; Miller and his comrades focused on the complex structure of plans and the production of behavior as well as the nature of memory. [54] Likewise, M.L.R Smith suggests that the cognitive processes inherent in strategy, along with the general structures of collective action and cooperation behind the "moral" dimension of how and why political communities hold together, are often ignored in strategy. [55] Both Lawrence Freedman and Kenneth Payne have recently made reference to cognitive dynamics of individual and group decisionmaking such as plans, scripts, and schemas or the heuristics and biases literature as useful ideas for strategists to examine. [56]

3 Strategy: A Computational Approach

3.1 The challenge of breaking the black box

A basic way to rethink the study of strategy is through the image of strategy itself as a **complex knowledge structure**. What is strategy? At a minimum, strategy may be regarded as a program for generating and maintaining a competitive advantage over an opponent. At maximum, it may be seen as an instrumental conceptual structure that constitutes a collective understanding of how to bridge the gap between a desired political end and political violence. Disputes currently rage over how to properly unify and/or contrast these and other varying perspectives.

[53]Miller, George A., Eugene Galanter, and Karl H. Pribram. *Plans and the Structure of Behavior*. Adams Bannister Cox, 1986.

[54]Gobet, Fernand, Jean Retschitzki, and Alex de Voogt. *Moves in mind: The psychology of board games*. Psychology Press, 2004, Miller, George A. "The magical number seven, plus or minus two: some limits on our capacity for processing information." *Psychological review* 63.2 (1956): 81.

[55]Smith, M.L.R., Quantum Strategy: The Interior World of War, *Infinity Journal*, Volume 3, Issue No. 1, Winter, 2012, pages 10-13.

[56]Freedman, Lawrence. *Strategy: a history*. Oxford University Press, 2013 and Payne, Kenneth. *The psychology of strategy*. Oxford University Press, 2015.

The theory and practice of strategy constitutes a complex and multilayered domain that is neither necessarily art nor science. When one adds in the cognitive and behavioral dimension of characterizing strategy, there has increasingly been enormous debate over what strategy is, how to represent it, and how to arbitrate between apparent contradictions and differences. Strategy remains (as Clausewitz suggested) both immensely simple and tremendously complex to characterize. Existing literature often describes strategy in terms of a bridge, theory of victory, narrative, or other conceptual structure linking goals to behaviors.

To strategize is to engage in a multifarious and ill-understood process that at a minimum can be said to involve analogy, representation, shared relational structures, reasoning processes, and folk psychological notions of the opponent and other relevant entities. [57] Strategy itself – what it is, how it might be used as an form of knowledge and belief – is a subject that deserves discussion. One could take some inspiration from research programs in thinking and reasoning[58]:

> The first area concerns understanding how thinking, reasoning, and decision making are influenced by world knowledge. One of the most important observations in early artificial intelligence and cognitive science research was the extraordinary richness of the knowledge required to understand even the simplest story or scenario (Clark, 1975; Minsky, 1977). Our thoughts effortlessly draw on rich knowledge of the physical and social worlds, not merely the logical forms of the sentences that we are hearing or reading; and such knowledge itself appears to have a fractal character (Chater & Oaksford, 2001). That is, explaining any given fact about the physical and social worlds appears to require drawing on yet further such knowledge, and so on indefinitely. While mathematical concepts, such as sets, groups, and the real line, can neatly be captured by a few axioms (although there is sometimes controversy about which axioms are most appropriate), real-world categories, such as chair, country, person, or belief, stubbornly resist such formalization (see Rips et al., Chapter 11). Rather, they appear to be part of an interdependent web of belief (Quine & Ullian, 1978), which is difficult, or perhaps even impossible, to characterize piecemeal.

The manner in which strategy functions as both an individual and shared device to help structure, organize, and direct our knowledge of the world into thinking, reasoning, and decision processes is broadly an area of study that could be very fruitful. Strategy is neither a way of selecting decisions (as often presented in the social sciences) nor a discrete preference (as many colloquially perceive it). As noted in the adversarial problem solving and adversarial reasoning literatures, social science approaches routinely underestimate the complexity

[57] Gordon, Andrew S. *Strategy representation: An analysis of planning knowledge*. Taylor & Francis, 2004.

[58] 2013-04-10). *The Oxford Handbook of Thinking and Reasoning (Oxford Library of Psychology)* (Page 19). Oxford University Press. Kindle Edition

of how agents reason over fairly simple adversarial games and tasks.[59] This disjuncture should not be surprising: representing strategy as an activity is one thing, explaining how a notional agent utilizes it and/or engages in it is another.

Is strategic reasoning one activity or a set of different activities that may be regarded as effectively modular? This seems to get at the heart of semantic inconsistency in different theories of strategy. Additionally, how is the opponent represented (or not) in strategy? And what about distinctions concerning how agents deal with uncertainty, temporal dimensions of the task, and the task structure? In many ways, concepts of strategic reasoning, planning, and problem-solving in strategic theory and practice still reflect outdated and since challenged ideas such as means-end reasoning in general problem-solving. In general, how does a strategic entity represent and reason about strategic problems? How much of strategy stems from what agents make of it? How do the answers to this question complicate an abstract conception of strategic theory?

Another aspect of this problem can be broadened to the question of how individuals and communities make strategy. Today, the paradox is that strategy and strategic are more popular than ever (every politician and analyst says we need a strategy) but few can convincingly describe what it is, assess its presence or absence, or agree how well a given actor is doing at it. The complexity of analyzing strategic theory at least partly explains this problem. Both implicit and explicit strategic processes both bound the decision horizons of the agents and communities that utilize them while being simultaneously altered and manipulated by those same entities.

Strategy must also ultimately be regarded as a collective activity undertaken by political communities and influenced as well by both formal and informal institutions. Collective inconsistencies, contradictions, and imperfections may complicate the formulation, representation, manipulation, and execution of strategy, for sure. However, from a different perspective, abstract strategies that are robust against both the inevitable surprises of implementation as well as the political and social struggle for power may be more useful than ones which are specialized to a fragile collection of elites.

How and why is strategy a collective pursuit? How can both strengths and weaknesses of the **politics** in **politics by other means** be represented through computational models or studied through computational methods writ large? And how do the answers to these questions compare to those outlined in the prior sections? This possible segment of the research work focuses on how institutional rationality impacts the representation and use of strategy, for better and worse. One can broaden this by including the elements of individual and collective strategic reasoning and problem-solving implied or explained in the prior section. Obviously strategy would not be useful either in terms of theory or instrumental device if there was no linkage between strategy and the images, heuristics, representations, and intuitive theories utilized by individuals

[59] Thagard, Paul. "Adversarial problem solving: Modeling an opponent using explanatory coherence." *Cognitive Science* 16.1 (1992): 123-149, and Kott, Alexander, and William M. McEneaney, eds. *Adversarial reasoning: computational approaches to reading the opponents mind.* CRC Press, 2006.

or the shared beliefs, protocols, conceptual structures, and assumptions seen in institutions and political communities. Strategy as a conceptual structure is represented, manipulated, and perceived by individuals and communities to further their own ends, but also structures behavior through pre-existing or given representations, manipulations, and perceptions.

One useful segment of research is simply the investigation of cognitive and computational aspects of strategic theories and the way in which individuals and communities construct, represent, manipulate, and utilize strategies as a function of strategic practice. How do strategic theories work as social, cultural, and cognitive constructions, representations, manipulations, and methods? Do the way in which different communities understand and utilize strategy and strategy-like activities pose challenges for general theory? How should we represent strategy – is strategy one thing or an umbrella term for a variety of different types of logics? Given the immense impediments strategy and rationality writ large what makes strategy possible? Is there a way to study strategy that balances recognition of the myth of an omniscient, rational ends-means calculator while nonetheless refraining from throwing the entire enterprise overboard? How consistent are our beliefs about what strategy is with observed behaviors?

3.2 The relevance, utility, and limitations of computational approaches

Broadly speaking, the prior paragraphs suggest several interesting approaches for strategic researchers. However, these approaches also necessitate different kinds of methods than have usually been pursued. To show why comptuational approaches may be relevant, this analysis first explains the general questions, why existing approaches have limitations, and the types of computational approaches that could be useful.

First, how can strategy be examined as a complex knowledge structure? The psychological and behavioral disciplines have analyzed how intuitive theories, concepts, categories, mental imagery, schemas, scripts, plans, and other tools provide scaffolding for us and help us organize our knowledge, beliefs, and intentions. Surely strategy itself could receive the same treatment.[60] Second,

[60]Seger, Carol A., et al. "Generalization in Category Learning: The Roles of Representational and Decisional Uncertainty." *The Journal of Neuroscience* 35.23 (2015): 8802-8812, Ashby, F. Gregory, and Leola A. Alfonso-Reese. "A neuropsychological theory of multiple systems in category learning." *Psychological review* 105.3 (1998): 442, Hampe, Beate, and Joseph E. Grady. *From perception to meaning: Image schemas in cognitive linguistics*. Walter de Gruyter, 2005, Narvaez, Darcia, and Tonia Bock. "Moral schemas and tacit judgement or how the Defining Issues Test is supported by cognitive science." *Journal of moral education* 31.3 (2002): 297-314, Braithwaite, David W., and Robert L. Goldstone. "Effects of Variation and Prior Knowledge on Abstract Concept Learning." *Cognition and Instruction* 33.3 (2015): 226-256, Fisher, Douglas H., Michael J. Pazzani, and Pat Langley, eds. *Concept formation: Knowledge and experience in unsupervised learning*. Morgan Kaufmann, 2014, Bobrow, Jerry. *Representation and understanding: Studies in cognitive science*. Elsevier, 2014, Kolodner, Janet L., and Christopher K. Riesbeck. *Friedman, Sarah L., and Ellin Kofsky Scholnick. The developmental psychology of planning: Why, how, and when do we*

given that the prior approach takes the strategic structure as a given and analyzes how it might be used by individuals and groups (or to model the behavior of individuals and groups), **how does the assumption of strategy as a socially shared knowledge structure explain many features of how strategy evolved, what it does for those who use it, and how it is changed by its social uses?** Harry Collins and others distinguish between mechanical actions, which do not have to be justified in the action selection process by an expectation of how others will see them, from socially constituted actions that are selected with a mind to how they will be perceived by others.[61] Much research lately has looked at the role of shared social cooperation, conflict, and behavior in human armed struggle, taking an explicitly cognitive, affective, and behavioral dimension.[62] One may also observe that in both areas, the traditional topics of foreign policy analysis and political psychology (groupthink, limitations on information search and selection, etc) are obviously relevant.[63]

New work by Freedman, Payne, and Thomas Rid suggests a promising new

*plan?. Psychology Press, 2014, Experience, memory, and reasonin*g. Psychology Press, 2014, Hartwright, Charlotte E., Ian A. Apperly, and Peter C. Hansen. "Representation, control, or reasoning? Distinct functions for theory of mind within the medial prefrontal cortex." *Journal of cognitive neuroscience* 26.4 (2014): 683-698, Heyes, Cecilia M., and Chris D. Frith. "The cultural evolution of mind reading." *Science* 344.6190 (2014): 1243091, Roese, Neal J., and James M. Olson. *What might have been: The social psychology of counterfactual thinking.* Psychology Press, 2014, Gallese, Vittorio. "Bodily selves in relation: embodied simulation as second-person perspective on intersubjectivity." *Philosophical Transactions of the Royal Society B: Biological Sciences* 369.1644 (2014): 20130177, Gentner, Dedre, and Albert L. Stevens. *Mental models.* Psychology Press, 2014., Rhodes, Marjorie. "Children's explanations as a window into their intuitive theories of the social world." *Cognitive science* 38.8 (2014): 1687-1697.

[61] Collins, Harry M., and Martin Kusch. *The shape of actions: What humans and machines can do.* MIT press, 1999.

[62] Payne, Kenneth. *The Psychology of Modern Conflict: Evolutionary Theory, Human Nature and a Liberal Approach to War.* Palgrave Macmillan, 2015, Gat, Azar. *War in human civilization.* Oxford University Press, 2006, Turchin, Peter. *War and peace and war: the rise and fall of empires.* Penguin, 2007, Norenzayan, Ara. *Big gods: How religion transformed cooperation and conflict.* Princeton University Press, 2013, Rosen, Stephen Peter. *War and human nature.* Princeton University Press, 2009, Friend, John M., and Bradley Thayer. "War and Aggression." *Evolutionary Perspectives on Social Psychology.* Springer International Publishing, 2015. 375-388, Atran, Scott, Robert Axelrod, and Richard Davis. "Sacred barriers to conflict resolution." *Science* 317 (2007): 1039-1040, Atran, Scott, and Robert Axelrod. "Reframing sacred values." *Negotiation Journal* 24.3 (2008): 221-246, Payne, Kenneth. *The psychology of strategy.* Oxford University Press, 2015, Smith, M.L.R., Quantum Strategy: The Interior World of War, *Infinity Journal*, Volume 3, Issue No. 1, Winter, 2012, pages 10-13, Erickson, Paul, et al. *How reason almost lost its mind: The strange career of Cold War rationality.* University of Chicago Press, 2013, Huddy, Leonie, David O. Sears, and Jack S. Levy, eds. *The Oxford handbook of political psychology.* Oxford University Press, 2013.

[63] Allison, Graham T. "Conceptual models and the Cuban missile crisis." *American political science review* 63.03 (1969): 689-718, Cohen, Eliot A., and John Gooch. *Military misfortunes: The anatomy of failure in war.* Simon and Schuster, 2006, Wohlstetter, Roberta. *Pearl Harbor: warning and decision.* Stanford University Press, 1962, Steinbruner, John D. *The cybernetic theory of decision: New dimensions of political analysis.* Princeton University Press, 1974, Jervis, Robert. *Perception and misperception in international politics.* Princeton University Press, 2015.

research program oriented around this theoretical perspective. [64] However, one decided weakness of the methodological approach is that, as Payne admits, a purely historical and qualitative methodological approach has limitations in its ability to suggest useful explanations for aspects of human behavior that cannot be directly observed from the historical record, especially in group and institutional settings.[65] One may also observe that the ability to manipulate, test, and perturb such implicit causal models is explicitly lacking from verbal and qualitative theories. Nonetheless, as Smith has observed earlier, it is difficult to believe that laboratory experimental conditions are a useful or desirable way to study the subject. Strategy is also a domain where, like cognitive and social modeling, mere fit to data (which, of course, may or may not exist and requires understanding beforehand) is not the sole object of validity. Computational approaches may help.

In many disciplines with complex research challenges, computatiuonal methods have augmented the usual reliance by researchers on qualitative, statistical, and formal methods. In fact, as philosopher Manuel De Landa observes, ours is as an age of "synthetic reason" distinguished by the prevalence of computational theories and methods of research in everything from the life sciences to the social sciences.[66] Moreover, one need only read the newspaper to see the impact of the data revolution on our everyday lives. [67]One should not take this, however, as somehow indicating that theory is obsolete, as many have.[68] Computers are simply tools and instruments. They can deliver answers but not questions. Nor is empiricism alone sufficient to answer many questions of interest in many research fields. [69]

This section identifies several areas in which strategic research on this issue can be improved by different methods that originate broadly from the computational sciences. Computational research can meaningfully contribute to strategy through one of several (or a combination of both) approaches. The first apporoach is mechanistic and often model-based and experimental in nature. The second is mainly observational in character and exploits the power of the computer as an investigatory instrument in several kinds of use cases. Neither approach (they are carciatures) should necessarily be regarded as inherently superior to the other in the absence of a defined research project. Nevertheless, their respective characteristics will be discussed below.

One potential model for strategic research lies in a mechanistic view of causation, which suggests that the goal of the researcher is to tease out – often

[64]All three have books coming out next year on the subject of new approaches to strategy involving these ideas in some shape or form.

[65]Payne, Kenneth. *The psychology of strategy.* Oxford University Press, 2015.

[66]DeLanda, Manuel. *Philosophy and simulation: the emergence of synthetic reason.* Bloomsbury Publishing, 2011.

[67]Mayer-Schnberger, Viktor, and Kenneth Cukier. *Big data: A revolution that will transform how we live, work, and think.* Houghton Mifflin Harcourt, 2013.

[68]Anderson, Chris. "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete." *Wired* 16.07 (2008).

[69]Indick, William. "Fight the power: the limits of empiricism and the costs of positivistic rigor." *The Journal of psychology* 136.1 (2002): 21-36.

through simulation modeling – the way in which complex causal chains are linked.[70] How could this be operationalized? First, research could formalize existing theories to test for hidden assumptions and other unanticipated aspects lurking beneath purely verbal theories and qualitative analyses. Second, by examining situations of interest and altering core assumptions, researchers could suggest new hypotheses. In rare cases when there is high-quality data, phenomological footprints of conflict could also be examined observationally. [71] Another related formulations of this basic idea suggest that modeling can be used for broadly heuristic purposes to increase our knowledge about underlying dynamics and mechanisms and refine, means-test, or otherwise perturb existing theories.[72] In this case, the theory broadly can be understood as something encoded in the model itself, a computational means of marrying deductive and inductive modes of inquiry. [73]

This, of course, raises the inevitable question of how such research can possibly be validated.[74] At a minimum, we can learn something from the way that this problem has been approached in the computational cognitive modeling community. In cognitive modeling, the mode of analysis is discovering how the relation between the environment, task, and the agent produces behavior. Theory development involves the construction of computer programs whose algorithms and data structures encode and formalize theories or aspects of theories. Empirical experiments are performed utilizing these programs in the hope that they may shed light on systems whose structure and operation are complex and often unobservable or difficult to quantify.[75] While other sciences focus on quantitative data, a computational theory often may be judged by its ability to present the full range of important behaviors of interest, the breadth of situations to which it is applicable, and the parsimony of the mechanisms it uses to explain behavior. [76] Finally, one may also observe that there is a key

[70]Hedstrm, Peter, and Petri Ylikoski. "Causal mechanisms in the social sciences." *Annual Review of Sociology* 36 (2010): 49-67, Machamer, Peter, Lindley Darden, and Carl F. Craver. "Thinking about mechanisms." *Philosophy of science* (2000): 1-25, Glennan, Stuart S. "Mechanisms and the nature of causation." *Erkenntnis* 44.1 (1996): 49-71.

[71]Holme, Petter, and Fredrik Liljeros. "Mechanistic models in computational social science." arXiv preprint arXiv:1507.00477 (2015), Johnson, Neil F., Elvira Maria Restrepo, and Daniela E. Johnson. "Modeling human conflict and terrorism across geographic scales." *Social Phenomena*. Springer International Publishing, 2015. 209-233, Weinberger, Sharon. "Web of war." *Nature* 471.7340 (2011): 566-568.

[72]Epstein, Joshua M. "Why model?." *Journal of Artificial Societies and Social Simulation* 11.4 (2008): 12.

[73]Thagard, Paul. *Computational philosophy of science*. MIT press, 1993, Kuipers, Theo AF. "Computational Philosophy of Science." *Structures in Science*. Springer Netherlands, 2001. 289-315, Axelrod, Robert. "Advancing the art of simulation in the social sciences." *Simulating social phenomena*. Springer Berlin Heidelberg, 1997. 21-40.

[74]Axtell, Robert L., and Joshua M. Epstein. "Agent-based modeling: understanding our creations." *The Bulletin of the Santa Fe Institute* 9.2 (1994): 28-32.

[75]Cohen, Paul R. *Empirical Methods for Artificial Intelligence*. MIT Press, 1995, Newell, Allen, and Herbert A. Simon. "Computer science as empirical inquiry: Symbols and search." *Communications of the ACM* 19.3 (1976): 113-126, Simon, Herbert A. "Artificial intelligence: an empirical science." *Artificial Intelligence* 77.1 (1995): 95-127, and Simon, Herbert A. "What is an explanation of behavior?." *Psychological Science* 3.3 (1992): 150-161

[76]Cassimatis, Nicholas L., Paul Bello, and Pat Langley. "Ability, Breadth, and Parsimony in

distinction between model fit and model performance as measures of validity. Some cognitive architectures in cognitive science and artificial intelligence can fit observed human data very well, but are not capable of tasks humans can perform or do not perform as well as humans do on those tasks. Other architectures cannot provide fit to data but are capable of performing complex and ill-understood human tasks at a human level and beyond.

Another model is very distinct, and lies more in the enhanced capacity of computers for representation and analysis relative to that of the human mind. There is an enormous literature on this, far bigger than that on the mechanistic model, and this paper will only partially summarize it.[77] Moreover, one should also observe that these methods can be fruitfully paired with more mechanistic and simulation-based approaches and increasingly are in many disciplines.[78] What is key to both, though more apparent in the fields of research described in the coming paragraphs, is a focus on the computer as critical research instrument akin to the microscope or the Large Hadron Collider.

Computers can help investigate theories by automating the process of the researcher's exploration and allowing it to be done at scale. Contrary to "big data" boosters, this does not render theory irrelevant. What it does do is make causal discovery more flexible. Increasingly, machine learning and data mining models are being used in place of traditional statistical models due to the way in which the latter provide a useful means of predicting outcomes or discovering causal relationships. Inquiries that might have been limited by the poverty of existing statistical methods can now be handled by more flexible and powerful machine learning and data mining models that can find interesting conclusions about datasets large and small.[79]

However, it should not be forgotten that many of these methods can be enhanced by the way in which computers can uniquely encode relations and concepts. Diagrammatic representations are key to science. They allow for the representation and manipulation of both the explanada (explanation) and the explanadum (thing to be explained). Causal diagrams, search graphs, knowledge ontologies, and network analysis can allow for detailed investigation of relational properties in an observed theory or system of interest. Their value stems from

Computational Models of HigherOrder Cognition." *Cognitive Science* 32.8 (2008): 1304-1322

[77]Kitchin, Rob. "Big Data, new epistemologies and paradigm shifts." *Big Data & Society* 1.1 (2014): 2053951714528481, Conte, Rosaria, et al. "Manifesto of computational social science." *The European Physical Journal Special Topics* 214.1 (2012): 325-346, Lazer, David, et al. "Life in the network: the coming age of computational social science." *Science* (New York, NY) 323.5915 (2009): 721, CioffiRevilla, Claudio. "Computational social science." *Wiley Interdisciplinary Reviews: Computational Statistics* 2.3 (2010): 259-271.

[78]Zhang, Haifeng. "Data-Driven Agent-based Modeling of Innovation Diffusion." *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems*. International Foundation for Autonomous Agents and Multiagent Systems, 2015, Janssen, Marco A., and Elinor Ostrom. "Empirically based, agent-based models." *Ecology and Society* 11.2 (2006): 37.

[79]Domingos, Pedro. "A few useful things to know about machine learning." *Communications of the ACM* 55.10 (2012): 78-87, Glymour, Clark, et al. "Statistical inference and data mining." *Communications of the ACM* 39.11 (1996): 35-41, Varian, Hal R. "Big data: New tricks for econometrics." *The Journal of Economic Perspectives* (2014): 3-27.

the way in which the computer may allow for the relevation and analysis of associations, relationships, structures, and the way in which they lead to a behavior of interest or are otherwise causally meaningful.[80]

3.3 The utility and caveats of computational approaches to strategy

It is not enough to simply suggest that these approaches could prove successful for strategy. Rather, several concrete use cases must be defined and the overall caveats of computational methods delineated. Computational approaches could have great utility for strategic research, but only if their downsides are kept in mind. They will never replace traditional methods, but they could very well complement them and help them become more effective. A frame story will be used to explore potentials for computational approaches in strategy. This frame story is an abstract yet also concrete narrative device used to illustrate an intellectual problem and how different methods of computation may help tackle it.

The frame story used as a common, comparative case for different types of computational approaches is the story of of how so-called "Machiavellian intelligence" and collective action in hierarchal societies developed. [81] Here we have a complex capacity taken seemingly for granted – the ability to both manipulate others and get large numbers of people to fight together in organized, hierarchal, systems. The former is obviously relevant to strategy, which includes cheating and deception and more broadly the act of overcoming a thinking, adaptive adversary.[82] The latter is critical to explaining the oldest and most powerful

[80] Newman, Mark. *Networks: an introduction. Oxford University Press*, 2010, Wasserman, Stanley, and Katherine Faust. *Social network analysis: Methods and applications*. Cambridge university press, 1994, Pearl, Judea. *Causality*. Cambridge university press, 2009, Bernstein, Abraham, Foster Provost, and Shawndra Hill. "Toward intelligent assistance for a data mining process: An ontology-based approach for cost-sensitive classification." *Knowledge and Data Engineering, IEEE Transactions on 17.4* (2005): 503-518.

[81] Gavrilets, Sergey. "Collective action and the collaborative brain." *Journal of The Royal Society Interface* 12.102 (2015): 20141067, Lyons, M., T. Caldwell, and S. Shultz. "Mind-reading and manipulationIs Machiavellianism related to theory of mind?." *Journal of Evolutionary Psychology* 8.3 (2010): 261-274, Turchin, Peter, and Sergey Gavrilets. "Evolution of complex hierarchical societies." *Soc. Evol. Hist.* 8 (2009): 167-198, Gavrilets, Sergey, and Aaron Vose. "The dynamics of Machiavellian intelligence." *Proceedings of the National Academy of Sciences* 103.45 (2006): 16823-16828, Gavrilets, Sergey, Edgar A. Duenez-Guzman, and Michael D. Vose. "Dynamics of alliance formation and the egalitarian revolution." *PLoS One* 3.10 (2008): e3293-e3293.

[82] Whaley, Barton. "Toward a general theory of deception." *The Journal of Strategic Studies* 5.1 (1982): 178-192, Bell, John Bowyer, and Barton Whaley. *Cheating and deception*. Transaction Publishers, 1991, Gooch, John. *Military deception and strategic surprise*. Psychology Press, 1982, Thomas, Timothy. "Russia's Reflexive Control Theory and the Military." *Journal of Slavic Military Studies* 17.2 (2004): 237-256, Jormakka, Jorma, and Jarmo VE Mls. "Modelling information warfare as a game." *Journal of information warfare* 4.2 (2005): 12-25, Gorelik, Vlad. "One step ahead." *Queue* 5.1 (2007): 24-31, Milevski, Lukas. "Revisiting JC Wylie's Dichotomy of Strategy: The Effects of Sequential and Cumulative Patterns of Operations." *Journal of Strategic Studies* 35.2 (2012): 223-242, Dolman, Everett. *Pure Strategy: Power and Principle in the Space and Information Age*. Routledge, 2004.

factor in strategy and warfare: cohesion, motivation, trust, and cooperation. [83] However, both are very difficult to study.

First, much of denial and deception involves not just the development of ingenious schemes for deceiving and manipulating the opponent, but also an inherent mentalistic theory of how that opponent will receive and use the information. Deception writ large involves manipulation of the perceptions and perceived realities of the target, which presupposes some knowledge about the mechanisms behind such mentalistic concepts.[84] The canonical approach in strategic deception, Barton Whaley's general theory, is a case in point. Whaley similarly relies on mentalistic conceptions of how messages are communicated to a target.[85] One core critique of these ideas argues that they are mainly qualitative in nature and substantially ignore the complexity of executing deception operations in regards to the capabities of human reasoning (or the "human window").[86]

Second, explaining collective action and cohesion necessitates showing how things hold together, given the basic expectation that they should not. Classical economic theory suggest that large organizations that provide common goods should fail to command the cooperation of their members. [87] Leadership certainly can potentially explain why some groups succeed or fail, but this obviously begs the question of why the foot soldiers should trust a leader to begin with. The revolutionary commander, for example, can easily turn conservative once in power.[88] Given that important differences over policy and strategy exist, how are they resolved?[89] Might there be a reason as well why certain groups are willing to hold together and endure great hardships and others cannot coop-

[83]Schneider, James J. "The theory of the empty battlefield." *The RUSI Journal* 132.3 (1987): 37-44, Murphy, Major Peter J., and Major Kelly MJ Farley. "Morale, Cohesion, and Confidence in Leadership." *The Human in Command*. Springer US, 2000. 311-331, Huntington, Samuel P. *The soldier and the state: The theory and politics of civil-military relations*. Harvard University Press, 1981, Bland, Douglas L. "Patterns in liberal democratic civil-military relations." *Armed Forces & Society* 27.4 (2001): 525-540, Rosen, Stephen Peter. "Military effectiveness: Why society matters." *International Security* (1995): 5-31, Lepgold, Joseph. "NATO's post-cold war collective action problem." *International Security* 23.1 (1998): 78-106, Wood, Elisabeth Jean. *Insurgent collective action and civil war in El Salvador*. Cambridge University Press, 2003, Adamsky, Dima. *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel*. Stanford University Press, 2010, Pollack, Kenneth Michael. *Arabs at War: Military Effectiveness, 1948-1991. U of Nebraska Press*, 2002.

[84]Bell, J. Bowyer. "Toward a theory of deception." *International Journal of Intelligence and Counterintelligence* 16.2 (2003): 244-279.

[85]Whaley, Barton. "Toward a general theory of deception." *The Journal of Strategic Studies* 5.1 (1982): 178-192,

[86]Moore, David T., and William N. Reynolds. "So many ways to lie: The complexity of denial and deception." *Defense Intelligence Journal* 15.2 (2006): 95-116, Michie, Donald. "Experiments on the Mechanization of Game-learning. 2Rule-Based Learning and the Human Window." *The Computer Journa*l 25.1 (1982): 105-113.

[87]Olson, Mancur. *The logic of collective action*. Harvard University Press, 2009.

[88]Aminzade, Ron, Jack A. Goldstone, and Elizabeth J. Perry. "Leadership dynamics and dynamics of contention." *Silence and voice in the study of contentious politics* (2001): 126-154.

[89]Westad, Odd Arne. *Decisive encounters: the Chinese civil war, 1946-1950*. Stanford University Press, 2003.

erat?[90] What happens when core political, cultural, and institutional questions relating to the making of strategy are not resolved and left to fester?[91]

Both have relevance to strategy. Capacities for deceiving and manipulating the enemy, our own allies, bureaucratic rivals, and constitutents, and sadly ourselves (self-deception seems endemic to any kind of security endevaor) seem to be latent in both the theory and practice of strategy. Conceptions of Soviet strategy and operations, for example, could not be viewed in isolation from the basic fact that the USSR's basic political and social system was based around massive deception.[92] Second, strategy depends on the ability to organize human violence at a large scale and often the problems of doing so have strategic implications. American strategy during the Civil War had to focus simultaneously on defeating the opponent while preserving support for the war itself.[93]

Several possible computational approaches could possibly be applied to both topics. First, purely in the mechanistic tradition, the following may be of use. All strategy involves probabilistic reasoning about other minds will do. Hence, simulation approaches from computational cognitive systems concerning plan recognition, nested probabilistic reasoning, and self-simulation could all be of use. [94] Cognitive models like these could help draw out the logic of what kind of reasoning is involved in issues of social trust, adversarial reasoning against an opponent, and recognizing the plans and intentions of others. Intention recognition, for example, may be useful for explaining cooperation.[95] Nested levels of reasoning are also key to understanding deception and exaggeration.[96] These methods, however, are elaborate to program and would likely necessitate a small-scale model in which a small number of simulated actors or causal aggregates are utilized. There also would not likely be a standard method available for verifiying the internal consistency of the model or validating its external validity.[97]

[90]Taylor, Brian D., and Roxana Botea. "Tilly Tally: WarMaking and StateMaking in the Contemporary Third World1." *International Studies Review* 10.1 (2008): 27-56.

[91]Strachan, Hew. "Strategy or alibi? Obama, McChrystal and the operational level of war." *Survival* 52.5 (2010): 157-182.

[92]Dailey, Brian D., and Patrick J. Parker. *Soviet Strategic Deception.* Hoover Institution Press, 1987.

[93]McPherson, James M. *Tried by War: Abraham Lincoln as Commander in Chief.* Penguin, 2008.

[94]Stuhlmller, Andreas, and Noah D. Goodman. "Reasoning about reasoning by nested conditioning: Modeling theory of mind with probabilistic programs." *Cognitive Systems Research* 28 (2014): 80-99, Lesh, Neal, Charles Rich, and Candace L. Sidner. *Using plan recognition in human-computer collaboration.* Springer Vienna, 1999, Kennedy, William G., et al. "like-me simulation as an effective and cognitively plausible basis for social robotics." *International Journal of Social Robotics* 1.2 (2009): 181-194.

[95]Han, The Anh, Lus Moniz Pereira, and Francisco C. Santos. "Intention recognition, commitment and the evolution of cooperation." *Evolutionary Computation (CEC), 2012 IEEE Congress on.* IEEE, 2012.

[96]Wang, Joseph Tao-yi, Michael Spezio, and Colin F. Camerer. "Pinocchio's Pupil: Using Eyetracking and Pupil Dilation to Understand Truth Telling and Deception in Sender-Receiver Games." *The American Economic Review* 100.3 (2010): 984-1007.

[97]Langley, Pat, John E. Laird, and Seth Rogers. "Cognitive architectures: Research issues and challenges." *Cognitive Systems Research* 10.2 (2009): 141-160, Duch, Wlodzislaw, Richard Jayadi Oentaryo, and Michel Pasquier. "Cognitive Architectures: Where do we go

A more potentially ecologically valid approach would be to use agent-based models, in which (on average) thousands of simulated "agents" scurry around a 2D map interacting with each other and the environment.[98] Agent-based modeling, for example, could show how certain deception techniques impact social organizations. [99] Moreover, they could also show trust and social relationships impact large-scale social cooperation and competition.[100] These similarly draw out the logic of complex behaviors, but do so in a much different way. The point of agent-based models is heterogeneous types of simulated people, complex interactions, and results that "emerge" from the bottom-up.[101] The tradeoff is that complex behaviors, processes, cognitive architectures, and individual and social knowledge are much more difficult to incorporate into the model. Additionally, the modeler faces a tough challenge in not only validating the complex model but also simply understanding what is going on. [102] Simple details, such as the activation order of the agents in each simulated time step, could distort results.[103] Finally, the simplicity of agent decision-making and behaviors may not be enough for the problem at hand.[104]

Moving away from the purely mechanistic paradigm, one might also utilize more observational methods. Data mining algorithms have been developed to detect deception.[105] These could be utilized in the service of developing better

from here?." *AGI*. Vol. 171. 2008, Vernon, David, Giorgio Metta, and Giulio Sandini. "A survey of artificial cognitive systems: Implications for the autonomous development of mental capabilities in computational agents." *Evolutionary Computation, IEEE Transactions on* 11.2 (2007): 151-180, Bryson, Joanna J., Will Lowe, and Lynn A. Stein. "Hypothesis Testing for Complex Agents." *NIST Workshop on Performance Metrics for Intelligent Systems.* University of Bath, 2001.

[98]Gilbert, G. Nigel. *Agent-based models*. Sage, 2008, Axelrod, Robert M. *The complexity of cooperation: Agent-based models of competition and collaboration*. Princeton University Press, 1997, Grimm, Volker, et al. "A standard protocol for describing individual-based and agent-based models." *Ecological modelling* 198.1 (2006): 115-126.

[99]Iiguez, Gerardo, et al. "Effects of deception in social networks." *Proceedings of the Royal Society of London B: Biological Sciences* 281.1790 (2014): 20141195.

[100]Sutcliffe, Alistair, and Di Wang. "Computational modelling of trust and social relationships." *Journal of Artificial Societies and Social Simulation* 15.1 (2012): 3.

[101]Bonabeau, Eric. "Agent-based modeling: Methods and techniques for simulating human systems." *Proceedings of the National Academy of Sciences* 99.suppl 3 (2002): 7280-7287.

[102]Windrum, Paul, Giorgio Fagiolo, and Alessio Moneta. "Empirical validation of agent-based models: Alternatives and prospects." *Journal of Artificial Societies and Social Simulation* 10.2 (2007): 8. Brown, Daniel G., et al. "Path dependence and the validation of agentbased spatial models of land use." *International Journal of Geographical Information Science* 19.2 (2005): 153-174, Wilensky, Uri, and William Rand. "Making models match: Replicating an agent-based model." *Journal of Artificial Societies and Social Simulation* 10.4 (2007): 2, Midgley, David, Robert Marks, and Dinesh Kunchamwar. "Building and assurance of agent-based models: An example and challenge to the field." *Journal of Business Research* 60.8 (2007): 884-893..

[103]Comer, Kenneth W. Who Goes First? An Examination of the Impact of Activation on Outcome Behavior in Agent-based Models. Diss. GEORGE MASON UNIVERSITY, 2014.

[104]Bryson, J. J. "Action Selection and Individuation in Agent Based Modelling." *Proceedings of Agent 2003: Challenges in Social Simulation* (2003): 317-330.

[105]Burgoon, Judee K., et al. "Detecting deception through linguistic analysis." *Intelligence and Security Informatics*. Springer Berlin Heidelberg, 2003. 91-101, Fuller, Christie M., David P. Biros, and Dursun Delen. "An investigation of data and text mining methods for real world deception detection." *Expert Systems with Applications* 38.7 (2011): 8392-8398,

theories of real world deception from observational data. More broadly, machine learning and data mining have been widely used in the social and behavioral sciences to answer difficult questions by automating the process of predicting or grouping variables of interest. [106] It is not hard to see how this could help theory development in strategy; supervised mixed-initiative machine learning has already proven useful in teaching agent systems to make inferences utilizing Army War College theories about Clausewitz. [107] A key issue, however, would lie in simply what goes into the model. Heavily supervised learning methods and expert systems are only as good as the experts they consult.[108] A similar problem exists with more flexible methods, with an added twist – one gets much less information about how the algorithm derived its results.[109]

Those familiar with special operations and counterterrorism will recognize an alternative – network analysis. Network analysis represents social structures as a set of relationships, allowing the visualization and manipulation of social stocks and flows that otherwise would remain hidden.[110] These have been used to examine a dizzying array of problems, from the social structure of firms to alliance dynamics in old Italy.[111] Key uses of social networks involve the mapping

---

Pang, Bo, and Lillian Lee. "Opinion mining and sentiment analysis." *Foundations and trends in information retrieval* 2.1-2 (2008): 1-135.

[106]Bartlett, Marian Stewart, et al. "Recognizing facial expression: machine learning and application to spontaneous behavior." *Computer Vision and Pattern Recognition*, 2005. CVPR 2005. IEEE Computer Society Conference on. Vol. 2. IEEE, 2005, Matari, Maja J. "Learning social behavior." *Robotics and Autonomous Systems* 20.2 (1997): 191-204, Effati, Meysam, Jean-Claude Thill, and Shahin Shabani. "Geospatial and machine learning techniques for wicked social science problems: analysis of crash severity on a regional highway corridor." *Journal of Geographical Systems* 17.2 (2015): 107-135, Hindman, Matthew. "Building Better Models Prediction, Replication, and Machine Learning in the Social Sciences." *The ANNALS of the American Academy of Political and Social Science* 659.1 (2015): 48-62, Burscher, Bjorn, Rens Vliegenthart, and Claes H. De Vreese. "Using Supervised Machine Learning to Code Policy Issues Can Classifiers Generalize across Contexts?." *The ANNALS of the American Academy of Political and Social Science* 659.1 (2015): 122-131, Athey, Susan. "Machine Learning and Causal Inference for Policy Evaluation." *Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Minin*g. ACM, 2015, Thelwall, Mike, David Wilkinson, and Sukhvinder Uppal. "Data mining emotion in social network communication: Gender differences in MySpace." *Journal of the American Society for Information Science and Technology* 61.1 (2010): 190-199.

[107]Lopez Jr, Antonio M., Jerome J. Comello, and William H. Cleckner. "Machines, the Military, and Strategic Thought." *Military Review* 84.5 (2004): 71, Lopez Jr, Antonio M., et al. "Clausewitz Meets Learning Agent Technology." *Military Review* 82.6 (2002): 10, Cleckner, William H., Gheorghe Tecuci, and J. Comello Jerome. "Instructable Agents for Strategic Center of Gravity Analysis." *AORS2001* (October 2001): 1-5.

[108]Collins, Harry M. *Artificial experts: Social knowledge and intelligent machines*. MIT Press, 1990.

[109]De Marchi, Scott. *Computational and mathematical modeling in the social sciences*. Cambridge University Press, 2005.

[110]Leoncini, Riccardo, Mario A. Maggioni, and S. Montresor. "Intersectoral innovation flows and national technological systems: network analysis for comparing Italy and Germany." *Research Policy* 25.3 (1996): 415-430.

[111]Uzzi, Brian. "Social structure and competition in interfirm networks: The paradox of embeddedness." *Administrative science quarterly* (1997): 35-67 and Padgett, John F., and Paul D. McLean. "Organizational Invention and Elite Transformation: The Birth of Partnership Systems in Renaissance Florence." *American journal of Sociology* 111.5 (2006): 1463-1568,

of organizations, the structure of geopolitical alliances, the long-run explication of literary history, and other countless cases in which social relationships matter.[112] Ontologies are a related type of formalism that show the hierarchal decomposition of a complex set of actors, concepts, and relationships.[113] Ontologies have, for example, been heavily utilized to develop taxonomies of hacks and hackers in cybersecurity research.[114] Ontologies are in some ways very related to network analysis, so not much time will spent overviewing them here beyond the fact that they are a principled and structured way to represent an information-rich domain.

Network analysis and ontologies both are useful because they allow for the structure of a domain, whether its social structure or knowledge structure, to be utilized to formalize understandings and make useful inferences. These strengths, however, are also their weakness. Because of the heavily structural approach they take, one must have some degree of justification that the formalism (for example, a graph of relationships between enitites) used is necessary for the task at hand. It may not be useful, for example, to represent a particular actor's knowledge or beliefs (in the context of deception) as an ontology unless the way in which concepts and subconcepts interact is of use to the research project. Likewise, if one is looking to explain the functioning of a complex organization in terms of trust and collective action, one also must acknowledge key uncertainties and choices made in how networks represent human agency, culture, and social social structure.[115]

Padgett, John F., and Christopher K. Ansell. "Robust Action and the Rise of the Medici, 1400-1434." *American journal of sociology* (1993): 1259-1319..

[112]Moretti, Franco. *Distant reading*. Verso Books, 2013, Padgett, John F., and Paul D. McLean. "Economic Credit in Renaissance Florence*." *The Journal of Modern History* 83.1 (2011): 1-47, Franzosi, Roberto. "The Return of the Actor. Interaction Networks Among Social Actors during Periods of High Mobilization (Italy, 1919-1922)." *Mobilization: An International Quarterly* 4.2 (1999): 131-149, Ebers, Mark. *The formation of inter-organizational networks*. Oxford University Press, 1999, Robertson, Maxine, Jacky Swan, and Sue Newell. "The Role of Networks in the Diffusion of Technological Innovation*." *Journal of Management Studies* 33.3 (1996): 333-359, Hafner-Burton, Emilie M., Miles Kahler, and Alexander H. Montgomery. "Network analysis for international relations." *International Organization* 63.03 (2009): 559-592.

[113]McGuinness, Deborah L., and Frank Van Harmelen. "OWL web ontology language overview." W3C recommendation 10.10 (2004): 2004, Gmez-Prez, Asuncin, Mariano Fernndez-Lpez, and Oscar Corcho. Ontological Engineering: with examples from the areas of Knowledge Management, *e-Commerce and the Semantic Web*. Springer Science & Business Media, 2006.

[114]Simmonds, Andrew, Peter Sandilands, and Louis van Ekert. "An ontology for network security attacks." *Applied Computing*. Springer Berlin Heidelberg, 2004. 317-323, van Heerden, Renier Pelser, Barry Irwin, and I. D. Burke. "Classifying network attack scenarios using an Ontology." *Proceedings of the 7th International Conference on Information Warfare and Security. Academic Conferences Limited*, 2012, Vorobiev, Artem, and Jun Han. "Security attack ontology for web services." *Semantics, Knowledge and Grid,* 2006. SKG'06. Second International Conference on. IEEE, 2006, Mouton, Francois, et al. "Towards an ontological model defining the social engineering domain." *ICT and Society*. Springer Berlin Heidelberg, 2014. 266-279, van Heerden, Renier, Heloise Pieterse, and Barry Irwin. "Mapping the most significant computer hacking events to a temporal computer attack model." *ICT Critical Infrastructures and Society*. Springer Berlin Heidelberg, 2012. 226-236.

[115]Emirbayer, Mustafa, and Jeff Goodwin. "Network analysis, culture, and the problem of

4 Conclusion: Strategies of the Artificial

It is true that computers have a mixed history in strategic affairs. However, this should not be reason to totally ignore their possible uses in strategic research. As argued throughout this paper, strategies are both complex human-created objects while also proxies and representations *for* and directors and structures *of* both individual and social attributes and processes. Because of this, computers can not only help illuminate previously ignored dynamics and questions in strategy, they might also help lead to qualitatively new theoretical refinements and concepts. This document represents my own attempt to explain how and why this might be the case, and it will evolve over time as its plans and intentions make first contact with the "enemy" (the problems of turning theory into research).

agency." *American journal of sociology* (1994): 1411-1454.