Chapter 2
Lewis Fry Richardson: A Personal Narrative

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Abstract This chapter is the personal story of how the author, just out of graduate school, encountered Richardson's two posthumous volumes, *Arms and Insecurity* and *Statistics of Deadly Quarrels*, and how these volumes helped her resolve key issues that had troubled her. What is theory and how does it differ from a model? The first volume pushed her to learn mathematics and, through various twists and turns, eventually to an understanding of the power of a mathematically written story. The second volume provided insights into data collection and measurement as well as a deeper understanding of the mechanics of mathematical modeling. Thus, the two volumes together gave her the basis for finally answering the questions from her graduate school days.

2.1 Introduction

When I finished graduate school in political science, I was left with a set of troubling, unanswered questions. I had found the debates of realism and idealism unsatisfying and believed that a science of international politics was both needed and possible. But I was baffled and confused about what I believed were the critical pieces of a science. What is 'theory'? Why is it important? What is a 'model' and how does it differ from 'theory'? Where do mathematics, statistics, and data fit? It was the work of Lewis Fry Richardson that, over the years, pushed and nudged me along a journey that finally led me to the answers. The combined volumes of *Arms and Insecurity* Richardson (1960a) and *Statistics of Deadly Quarrels* Richardson (1960b) became the 'intellectual bibles' for my search. They were bewildering at times, frustratingly challenging at others, but they ultimately teased me into an understanding of the bits and pieces that transform a study of international politics into a science of international politics.

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My journey with Richardson began when I was a graduate student at the University of Michigan. *Journal of Conflict Resolution* had recently been founded and the graduate students were made part of the organization team. An initial topic of conversation was how and when a special issue might be devoted to this meteorologist's unpublished notes on conflict and war. Work was under way to compile the extensive notes into publishable book form following Richardson's death, but it was felt that the significance of the material might go unrecognized by the potentially most relevant audience – the social sciences – because of its mathematical nature. Thus, it seemed an obvious idea to combine the launch of a journal dedicated to analytical research on conflict with a layman's introduction to Richardson's mathematical approach to issues of conflict. A long review article by Rapoport (1957) in a special issue of the journal served as my introduction to this amazing work.

When *Arms and Insecurity* was published in 1960, I was eager to tackle the 'real thing'. But while the book was captivating, it also posed enormous challenges. The 'dialogues' – Richardson talking to himself as he puzzled his way through a question – were exciting and provided a wonderful insight into the strategy of thinking about a research problem. When the dialogues led to the 'story' of two statesmen arguing how best to protect their country against the other, I was intrigued. But when the story was translated into two equations, confusion began. Richardson waived a mathematical wand, and out of the equations came the 'explosion' of 'war' – and confusion turned into amazement. It was magic. Richardson had pulled a rabbit out of a hat!

Since I had not taken mathematics in college, my mathematical training had ended with high school trigonometry. I understood algebraic equations, but I had never encountered the symbol dx/dt. Moreover, Richardson's ability to move from verbal language to mathematics was baffling. My only encounters with the transition between verbal language and mathematics were word problems: How long would it take to go from X to Y when traveling at …? But most mystifying of all was Richardson's ability to draw conclusions about 'war' and 'peace'. How did he know that certain inequalities between parameters of the equations would produce an 'explosion?' Where did these rabbits come from?

Puzzling over the equations for hours forced me to conclude that my mathematical training was deficient. If I was going to be able to understand Richardson's work, I had to go back to school. I had recently finished my Ph.D. and followed my husband to his first academic job at Indiana University, so there was a breathing spell of free time to explore mathematics. I began with the basics – calculus – and proceeded through the 'bread and butter' sequence of college mathematics courses. It was a slow and, at many points, difficult process – mathematics was a very different world for someone coming from the social sciences. But bit by bit I acquired the basic vocabulary, grammar, and mode of thinking of this new and intriguing world.

When my first teaching job materialized at Indiana University, I came across a book that seemed to compliment Richardson's work. *Introduction to Models in the Social Sciences* by Lave & March (1975) was similar to Richardson in three ways. First, Richardson had begun his arms race model with a question: Why do two peaceful states end up in a violent conflict? Similarly, Lave & March illustrate the importance of starting with a question. They explore a series of simpler questions: Why do high school friends get assigned to adjacent rooms in freshman college dorms? Why are the students who ask silly questions in class typically athletes? Why do women who attend all-women high schools perform at a higher level in college than women at co-educational high schools?

Second, Richardson's question led him to formulate a story about two statesmen from two different states wanting to protect their respective countries from possible aggression by the other. Similarly, Lave & March provide verbal stories that answer each of the questions raised in their examples. Third, both Richardson and Lave & March draw conclusions from their stories. In each case the authors use their stories to predict something new, an observable phenomenon that, as Lave & March put it, would follow if the stories were in fact 'true'.

But there was a significant difference between the authors. Unlike Richardson, Lave & March never translate their stories into mathematics. Instead, they draw verbal conclusions from each story. As I examined these verbal conclusions, I found myself troubled. Some seemed direct and reasonable, but others were far less clear. This was an intriguing contrast with Richardson's analyses. Although I was still not competent to follow all the details, Richardson's conclusions appeared less ambiguous and far more convincing. Thus, Lave & March (1975) reinforced the significance of questions and stories, but simultaneously made me aware of the potential value of translating a story into mathematics.

As I moved further into my research career the focus on theory and mathematical modeling was overshadowed by another part of the science puzzle. Singer (1969) argued that if the study of international politics was to go beyond the philosophical realist/idealist debates to become a science, it was critical that arguments be subjected to empirical verification. Singer called for brush-clearing research in which the major hypotheses of the field would be evaluated with data.

Obtaining data relevant to international issues, however, was not a simple matter. Thus, the focus of the newly emerging field of 'quantitative international politics' turned to issues concerning data: How do you define the variables of interest (e.g. national power, conflict, war, crisis), what are the appropriate sources from which to extract 'data', how can data extraction be made reliable? Some argued that relevant data could be created in laboratories as in the Inter Nation Simulation (Guetzkow, 1963) where people played the roles of statesmen and interacted according to rules believed to govern the international system. But the validity issues inherent in these laboratory representations seemed insurmountable and the field moved instead towards real time data and the subsequent creation of large datasets.

The resultant data movement had three prongs: (1) the collection of daily events in contemporary time to better understand crises (e.g. WEIS,[1] COPDAB[2]), (2) the compilation of major historical international crises, e.g. wars (COW[3]), and (3) the collection of national attributes (such as DON[4]). The datasets were typically the work of independent researchers, each concerned with specific questions that dictated both the definition of variables and the type of data to be collected. Consequently, as the various datasets were compiled, comparisons became important and questions arose as to the 'true' meaning of concepts like 'war'. Did one 'operationally' define a 'war' as an overt declaration by one state against another? Or was it an event in which at least 100 combatants were killed? Or was 'war' just the end point of a scale that began with one human killing another?

Fascinated by these issues and wanting to understand the art and science of data collection better, I purchased *Statistics of Deadly Quarrels*, which contained one of the early datasets relevant to conflict and war. Initially, my interest was in the dataset that comprised the first half of the volume. As had been true in *Arms and Insecurity*, the volume began by describing the author's thinking process behind the collection of data and was both captivating and enlightening. Part of the discussion consisted of his definition of the key variable of interest – a 'deadly quarrel'. Richardson's Quaker background made him primarily interested in those situations in which one human killed another, i.e. human conflicts that ended in at least one death. Murder was simply one end of a scale that ended in a world war.

This different but creative way of conceptualizing and measuring a variable made me aware of the fact that 'data' do not exist independent of their operational measurement. The operational definition of a variable would necessarily determine the kinds of questions that could be answered using a given dataset. This realization led me to conclude that collecting data to test a specific hypothesis was important, but collecting data for a data bank could be of limited value. The operational definition used to collect the data for a data bank is unlikely to fit many research questions. In fact, the existence of data banks may have the unfortunate effect of pushing scholars to adjust their research questions to fit the definitions used to collect the data bank variables.

Although my purchase of *Statistics of Deadly Quarrels* had been motivated by Richardson's dataset, I discovered that the book also contained valuable information relevant to my original concerns. It is actually two books in one. While the first part consists of Richardson's discussion of his data collection procedures and the resultant dataset, the second part is, in many respects, an answer to Singer's call for a brush-clearing of old arguments about conflict and war. The second half of the book puts the dataset of the first half up against a variety of age-old arguments: Do borders cause wars? Do differences in religion lead to conflict? Is economics the

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[1]McClelland (1978).

[2]Azar (2009).

[3]Singer & Small (1972).

[4]Rummel (1972).

source of conflict? Each chapter looks at one of these questions and, using the dataset, either formulates hypotheses that are statistically tested, or, in a few cases, develops stories that lead to the formulation of simple mathematical models. It was Richardson's use of these two forms of analyses that brought me back to my original queries. The contrast clearly posed the question: What was the difference – if any – between the statistical test of a hypothesis and the creation of a mathematical model?

This question became increasingly pressing as statistics began to permeate the discipline. The field's focus on data collection and hypothesis testing necessarily required decision rules that could provide guidelines for rejecting hypotheses. Like many others, I joined the statistics bandwagon and began my education in this new set of tools. But my study and use of statistics increased my puzzlement. Statistics was mathematics. Did that mean that the application of statistics to data was mathematical modeling? Are chi square tests and correlations mathematical models? How did the equation for a correlation coefficient differ from the equations of the arms race model? Were the arms race equations a set of hypotheses that needed to be tested? Was there a difference between a mathematical model and a statistical analysis?

As I pondered these issues, I was asked to write a review of *Mathematics and Politics* by Alker (1965). Without explicitly noting the difference between a statistical analysis and mathematical modeling, Alker's survey of both made the contrast between the two explicit. The difference became obvious. The goal of statistics was to make coherent decisions: Did the data support the hypothesis? But the goal of mathematical modeling was to tell a story: How does an arms race begin and evolve? They were both mathematical enterprises, but their purpose was very different.

I returned to *Statistics of Deadly Quarrels* in an effort to better understand this difference. Many of Richardson's questions were simple hypotheses, and so he used his dataset together with statistical tests to confirm or reject. A few others, however, led him to formulate stories about a process he believed underlay the answer to the question. I found one such story to be of particular significance. It was a story about how nations might form alliances to fight a war. This story was especially valuable because Richardson used probability theory – combinations and permutations – a form of mathematics I understood. For the first time, I was able to follow Richardson's translation from a verbal story into its mathematical counterpart and witness the emergence of a testable conclusion.

While the story was too simple to be believable, its very simplicity made it possible to observe the mathematics in action. As Richardson put it, if his story were true – a phrase often used by Lave & March – then one would observe a specific distribution of the number of wars over the number of nations on either side: i.e. the number of wars in which one nation fought one nation, the number of wars in which one nation fought two nations, etc. Thus, the simple story about how nations formed alliances necessarily implied that types of wars (one nation against another, one against two, etc.) would result in a particular, i.e. predicted, distribution. The predicted distribution was a hypothesis and as such could be tested by comparing it to the distribution found in Richardson's dataset. For the first time, I saw the critical link between stories, mathematical modeling, and hypotheses. The translation of a story into a mathematical representation could lead to testable hypotheses.

The bits and pieces of answers to the questions from my graduate school days were emerging: the relevance of an initial question, the role of story-telling, the importance of mathematics, the difference between mathematical models and statistics. But gaps still remained, and the pieces still did not fit together. Where do the questions that initiate stories come from? How are stories developed? What information is needed to tell a story? How do you translate a story into mathematics? What is the difference between testing a hypothesis or telling a story, translating it into mathematics, and generating a hypothesis for testing? And finally, and most significantly, what happened to 'theory?'

In an attempt to fill the gaps, I returned to Richardson and Lave & March. Richardson had begun his arms race model with a story. Lave & March gave example after example of stories. But what constituted a 'story?' Merriam Webster proposes that a story is 'an account of incidents or events … pertinent to a situation'. This definition suggested that a string of time-dependent sentences would qualify as a story if the sentences all referred to the same situation.

Trying out the definition, I constructed a 'story': 'I'm sitting in a coffee shop and a young lady enters, walks to the counter, and orders a cappuccino. She pays her bill, the waitress puts the money in the register, and makes the drink. The waitress hands the drink to the young lady who then goes to a vacant table, sits down, and enjoys her purchase.' According to the definition, I had created a story: a set of sequentially connected sentences concerning an incident. But despite the dictionary definition, the set of sentences didn't look like anything I would call a 'story'. I tried the exercise multiple times before becoming convinced that there was more to the 'story' concept than captured by the dictionary.

I headed back to Richardson's arms race and the Lave & March examples and discovered that I had overlooked a critical piece. Richardson's arms race story began with a question, the desire to understand the onset of war – he had a reason, a purpose, a question that he was attempting to understand. Likewise, Lave & March were curious about dorm friendship patterns or why all-women high schools provided a better education for college-bound women. In short, stories begin with a question. Thus, a story has a purpose: it is designed to answer a question, to explain why something happened. My sequentially connected sentences about the lady in the coffee shop was not triggered by a question, thus the set of sentences explained nothing. Perhaps if the young lady's boyfriend had been killed an hour earlier, the question might have been about the woman's potential complicity in the event. But in isolation, the coffee shop episode was of no interest, it explained nothing, it answered no question. It wasn't a story.

With this revelation in hand, I turned to storytelling by considering questions for which I wanted answers, events that I wanted to explain. But the task was daunting as I began by asking questions about wars, failed states, the reasons for revolutions. I quickly discovered that the questions were too big, or I didn't know enough to formulate a story to provide an answer. Then, taking a cue from Lave & March, I realized that if I looked around in my daily life I was frequently asking questions. They were tiny questions compared to a question about why wars occur, but they were questions that were nevertheless looking for answers. Moreover, they were questions for which I had enough information to construct a story. I decided to use these daily questions as a training ground to teach me how to recognize questions and formulate stories.

It quickly became obvious that lots of things were happening daily that I didn't understand, that didn't make sense. Why were there potholes in one part of town and not another? Why was grass growing alongside the road in a desert? Why did caterpillars congregate at certain intersections on country roads? Why was it so difficult to find a common time for three retired women to share lunch? As I spun stories about each question, I began to understand how questions arise. A question arises when an event occurs that contradicts what is expected. Potholes are the consequence of erratic temperatures during rough winters, but this should happen randomly throughout town. Since deserts receive little rain, how is it possible for grass to grow along a road? Caterpillars have limited cognitive abilities, so why are there congregations at 'intersections'? Retired folks no longer have work commitments, so why is it so difficult to find a mutual free time to meet for lunch? Richardson's story about an arms race was similar. His question was why war occurred when statesmen in opposing nations were attempting to prevent war through armament buildups?

I had begun to understand how questions arise and stories were developed. But I was still unclear about the use of mathematics. While I was convinced that translating a story into mathematics could produce a testable hypothesis, I was perplexed as to how to make the translation and use the mathematics to generate hypotheses. Then serendipity stepped in.

A colleague asked me to join forces on a methods textbook. The topics of the proposed text were to be typical, e.g. survey research, experimental design, etc. However, my colleague suggested that we approach the material from a very different perspective. He proposed that the text focus on questions about political processes and provide answers to those questions by constructing stories similar to those found in Lave & March. The stories would then be translated into the mathematics of basic logic – propositional calculus – and using the mathematics of propositional calculus, conclusions (hypotheses) could be generated. The resultant hypotheses would then be tested with a given methodology (e.g. survey research). To illustrate the process, my colleague had written a variety of political stories about congress (his area of expertise), translated them into propositional calculus, and using the mathematics of propositional calculus drawn some intriguing conclusions.

The methods text never materialized (too avant-garde for the publisher), but my colleague's examples became the critical final step towards answering my questions. Richardson's probability model provided the insight into how a mathematical translation occurs and how the mathematics of probability could generate a testable hypothesis. But the language of probability theory seemed too limited to be useful for stories about politics. Propositional calculus, however, appeared both accessible and useable. It was time for more study.

Perhaps the most important thing to come from my dive into the rudiments of propositional calculus, was the insight it gave me into the significance and meaning of theorems. Understanding the power of theorems led to my discovery of the home of the rabbits. I learned that everything is implicit in the original definitions, assumptions, and the basic rules of a form of mathematics. These are the building blocks needed to prove theorems. Theorems are just restatements of combinations and permutations of the definitions and assumptions given the accepted mathematical rules. The conclusion of a theorem is a restatement of the original assumptions. Theorems are then used to prove more theorems. Thus, it is always there – the rabbit is in the initial definitions and assumptions. A 'new' rabbit is the original one wearing different clothes. By translating a story into mathematics, it is possible to use theorems that point to 'new', i.e. implicit, information embedded in the assumptions that constitute the statements of a story. This is the power and value of mathematical languages. You begin by accepting as 'true' a basic set of premises and when you sign that contract you are given a panoply of consequences through theorems that show you all the other things that are then 'true'.

Propositional calculus is a very primitive form of mathematics compared to differential equations, but the underlying logic is the same. Theorems begin with definitions and assumptions that are accepted as 'true' and proceed to demonstrate that, given the rules of mathematics, another set of things are also true. Richardson's deductions about 'war' and 'peace' are implicit in the mathematics of differential equations used to capture the story of an arms race. Richardson's conclusions about 'war' and 'peace' come from the mathematics of differential equations. Thus, the link between a story translated into mathematics, and a generated hypothesis is transparent to anyone trained in that form of mathematics. This cannot be said about conclusions from purely verbal stories. This was the difference between Richardson's analyses and the verbal conclusions of Lave & March.

As I learned the specifics of propositional calculus and followed the examples of my colleague's political stories, the translation and hypothesis generation processes became clearer and the value of mathematics more obvious. Translation forces one to identify the key components of a story and the principle links between the components. This makes the outlines of a story obvious. The use of theorems to unambiguously draw conclusions links the theoretical world to the empirical. Moreover, drawing hypotheses from mathematical models can produce insights not seen otherwise.

To briefly see how mathematical modeling might work, let us consider Richardson's story about two statesmen in two neighboring states who are concerned about the possible intentions of the other. To translate this story into the mathematics of propositional calculus we need two sets of definitions. The first is the concept of an 'atom', defined as a simple statement that can be either True or False. In the arms race model, we can identify the following 'atoms:' Using symbols to represent the atoms we define:

X = the head of state X wishes to protect state X
A = the head of state X puts considerable resources into armaments
Y = the head of state Y wishes to protect state Y
B = the head of state Y puts considerable resources into armaments

It is easy to see that each of these statements could be assigned the value of T or F, e.g. the head of state does wish to protect state X (i.e. statement is T) or the head of state X does not wish to protect state X (i.e. the statement is F).

The second component of propositional calculus is the set of four ‘operators’ that link atoms to produce compound statements:

‘and’ (^)
‘or’ (v)
‘not’ ($\sim$)
‘implies’ ($\rightarrow$)

Thus, the first part of the story might be translated into:

$X \rightarrow A$

If the head of state X wishes to protect state X, then the head of state X puts considerable resources into armaments and

$Y \rightarrow B$

If the head of state Y wishes to protect state Y, then the head of state Y puts considerable resources into armaments.

To continue the story, we define

C = state Y feels threatened
D = state X feels threatened

and then construct the compound statements:

$A \rightarrow C$

If the head of state X puts considerable resources into armaments, then state Y feels threatened and

$B \rightarrow D$

If the head of state Y puts considerable resources into armaments, then state X feels threatened.

To make the story simple let’s define

E = state X declares war on state Y
F = state Y declares war on state X

Then $C \rightarrow F$

If state Y feels threatened by state X, then state Y declares war on state X

$D \rightarrow E$

If state X feels threatened by state Y, then state X declares war on state Y.

Finally, we define

W = states X and Y go to war.

and propose the compound proposition

$(F^{\wedge}E) \rightarrow W$

If state Y declares war on state X and state X declares war on state Y, then states X and Y go to war.

The theorems of propositional calculus tell us that if we begin with the atoms X and Y, together with the above story, we can conclude that the two states will go to war. Namely, given X and Y, i.e. two states with statesmen that wish to protect their state by putting resources into armaments, then W is a consequence, i.e. these two states will go to war.

Another intriguing conclusion that emerges from this story is the following: Using theorems from propositional calculus and skipping a few steps, the following can be concluded:

$$\sim W \rightarrow \sim (F \wedge E) \rightarrow (\sim F \, v \sim E) \rightarrow (\sim D \, v \sim C) \rightarrow (\sim B \, v \sim A)$$

This deduction says that if the story is true, then it should also be the case that when there are two (neighboring) states that have not gone to war it must be the case that at least one or both of those two states did not put considerable resources into armaments.Clearly, the above translation is overly simplistic. Like the translation of a text from one language to another, the process of translating a verbal story into a mathematical language is more an art form than a science. For any given verbal story there are many possible mathematical translations. We could for example have made the story more complicated by having only one state declare war and then the other retaliate. In this particular case, the conclusions are unlikely to be very different. However, it will be the case that different representations can lead to very different conclusions.

Propositional calculus was essentially the last step in my journey. I had the pieces needed to answer my graduate school questions. Stories are at the heart of theories. Theories, like stories, begin with a question and are designed to provide an answer to the query; theory/stories explain something. Casting a story in the language of mathematics – mathematical modeling – makes it possible to unambiguously produce conclusions, i.e. hypotheses, (deductions) that provide new insights and may be empirically verified. Empirical tests of deductions using statistical decision rules provide support for or against the original story. Theory and mathematical modeling are not equivalent; the latter provides a medium for evaluating the former. Mathematical modeling and statistical analyses are both mathematical enterprises, but they are used towards different ends. Mathematical modeling is an aid in the story-telling process while statistical analyses can provide the rules for empirical evaluation of the story. The story comes first and then its mathematical restatement provides the tool that produces new insights (hypotheses) to be evaluated. Data and statistics then follow to determine the empirical validity of the hypothesis and thus the grounds for determining the viability of the story.

Richardson had a profound effect on my life and career. *Arms and Insecurity* pushed me to learn mathematics and, through various twists and turns, eventually to an understanding of the power of a mathematically written story. *Statistics of Deadly Quarrels* provided both insights into data collection and measurement as well as a deeper understanding of the mechanics of mathematical modeling. Thus, the two volumes together gave me the basis for finally answering the questions of graduate school days.[5]

References

Alker, Hayward (1965) *Mathematics and Politics*. New York: Macmillan.

Azar, Edward E (2009) *Conflict and Peace Data Bank (COPDAB), 1948–1978.* Ann Arbor, MI: Inter-university Consortium for Political and Social Research, www.icpsr.umich.edu/icpsrweb/ICPSR/studies/07767.

Gillespie, John V; Dina A Zinnes, Gurcharan S Tahim, Philip A Schrodt & R Michael Rubison (1977) An optimal control model of arms races. *American Political Science Review* 71(1): 226–244.

Guetzkow, Harold et al. (1963) *Simulation in International Relations: Developments for Research and Teaching*. Englewood Cliffs, NJ: Prentice-Hall.

Lave, Charles A & James G March (1975) *An Introduction to Models in the Social Sciences.* New York: Harper & Row. [Reprinted 1993: Lanham, MD: University Press of America.]

McClelland, Charles A (1978) *World Event Interaction Survey.* Ann Arbor, MI. Inter-university Consortium for Political and Social Research, www.icpsr.umich.edu/icpsrweb/ICPSR/studies/5211.

Rapoport, Anatol (1957) Lewis F Richardson's mathematical theory of war. *Conflict Resolution* [now *Journal of Conflict Resolution*] 1(3): 249–299.

Richardson, Lewis F (1960a) *Arms and Insecurity: A Mathematical Study of the Causes and Origins of War.* Pittsburgh, PA: Boxwood.

Richardson, Lewis F (1960b) *Statistics of Deadly Quarrels.* Pittsburgh, PA: Boxwood.

Rummel, Rudolph J (1972) *The Dimensions of Nations*. Beverly Hill, CA: Sage.

Singer, J David (1969) The incomplete theorist: Insight without evidence. In: Klaus E Knorr & James N Rosenau (eds) *Contending Approaches to International Politics*. Princeton, NJ: Princeton University Press, 110–128.

Singer, J David & Melvin Small (1972) *The Wages of War, 1816–1965: A Statistical Handbook.* New York: Wiley.

Zinnes, Dina A (1980) Three puzzles in search of a researcher. Presidential address. *International Studies Quarterly* 24(3): 315–342.

[5]For examples of how I drew on Richardson in my own work, see Gillespie et al. (1977) and Zinnes (1980).

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