Researchers in scientific specialties and invisible colleges tend to cite each other in their written communications and especially in the journals devoted to those specialities. Such citations form a network through which there are many influence paths. The main paths through such citation networks contain the key intellectual developments in these scientific fields. If a specialty hangs together as a coherent field of research, one would expect that the citations within the field's journal should reflect the history of that field and exhibit the degree of interconnectedness among the different researchers and their special subgroups. Further, to the extent that a field is self-contained (i.e., not borrowing on other fields for its key intellectual developments), the citation network within the journal should contain one or more main paths on which are located many of the key intellectual developments of the field. These ideas are tested using citations in fifteen volumes of the Journal of Conflict Resolution *published from 1957 to 1971.*

Scientific Influence

An Analysis of the Main Path Structure
in the Journal of Conflict Resolution

KATHLEEN M. CARLEY
Carnegie Mellon University

NORMAN P. HUMMON
University of Pittsburgh

MARTHA HARTY
Carnegie Mellon University

The late 1950s and 1960s saw the emergence of an interdisciplinary scientific movement focused on developing a "science of peace," more specifically, a general theory of human conflict and conflict resolution. The research center that sponsored this movement and served as the focus of its activity for some fifteen years was eventually closed down, and its founders returned to more

traditional institutional settings. However, their failure to create a new science, replete with its own strong covering theory and methodologies, provides insights into the origins of new scientific fields. In particular, the movement provides a counter example—a field that emerged but failed to fulfill expectations of rapid theoretical development.

Social as well as intellectual factors are at work in the development of new fields (Ben-David and Collins 1966; Edge and Mulkay 1976; Kuhn 1962). The structure of a field can be characterized, in part, by the structure of its literature (Garfield 1979; Small and Griffith 1974a, 1974b). In this article, we examine the development, and ultimate dissolution, of the early push for a science of conflict resolution by examining the structure, over time, of its literature. To do this we employ a structural technique, to be described later, called main path analysis. We play off the results of this structural analysis against the detailed historical analysis of this movement conducted by Harty and Modell (1991). A historical analysis has the advantage that it can locate the institutional context, provide rich descriptions, and explore multiple aspects of careers of the key actors. A structural analysis of historical data such as main path analysis has the advantage that it can control for the influence of institutional context while examining the influence of ideas and theories. Comparing and contrasting results of these two techniques provides a more detailed, multilevel understanding of the historical period. Such an understanding may provide us with insights into which factors might systematically affect the successful emergence or dissolution of a new scientific field.

In describing the conflict resolution movement, we rely heavily on a detailed historical analysis conducted by Harty and Modell. Their account begins by describing the upsurge of national security studies among American social scientists in the postwar period.

> Among the wide array of studies undertaken in this first postwar decade, three connected clusters are notable: research on domestic sources of security policy, much of it sponsored by such champions of mainstream social science as the Social Science Research Council and the Carnegie Corporation of New York; examination of attitudinal causes of international conflict, a central concern of UNESCO; and, perhaps most ambitious and idealistic of all, attempts to define and establish a new interdisciplinary "science of peace." This last approach was exemplified by a movement that focused on developing a general theory of human conflict and conflict resolution. This ambitious research movement emerged at the University of Michigan in the late 1950s, founding both the *Journal of Conflict Resolution* and the Center for Research on Conflict Resolution. (Harty and Modell 1991, 721)

The first issue of the *Journal of Conflict Resolution: A Quarterly of Research Relevant to War and Peace* (*JCR*) appeared in March 1957. It was

put together by Robert Hefner and William Barth, then graduate students at the University of Michigan; and an editorial committee that included economist Kenneth Boulding, sociologist Robert Cooley Angell, a director of the UNESCO research project on Tensions Affecting International Understanding, psychologist David Katz, game theorist Anatol Rapoport, and other prominent social scientists at Michigan. Authors in the first issue included M. Quincy Wright, Morris Janowitz, Thomas Schelling, Daniel Levinson, and Harold Guetzkow.

The focus of the journal was on developing an integrated interdisciplinary theory of conflict. Indeed, its opening editorial (vol. 1, pp. 1-2), probably written by Kenneth Boulding, stated that "out of the contributions of many fields, a general theory of conflict is emerging." Over the next several years, the Center for Research on Conflict Resolution was founded, also at Michigan, and a great deal of effort was devoted to launching the new interdisciplinary science of conflict.

Fifteen years later, in 1971, the University of Michigan Board of Regents closed the Center for Research on Conflict Resolution. By moving to Yale and the editorship of Bruce Russett, the *JCR* continued, although now based at a much more traditional center of work in International Relations. Scientific research related to peace continued to appear in the *JCR* and other journals, but the original impetus for a general theory of conflict and conflict resolution had ended, particularly the focusing of efforts that had been attempted by the University of Michigan Center. As noted by Harty and Modell, there are many factors that led to the demise of the emerging new field, including its identification with political activism on the Michigan campus. However, they note,

> Most important is the internal problem: the movement's failure to fulfill early promises of discernible progress toward a general, integrated, interdisciplinary theory of human conflict, the most prominent basis offered by its sponsors for distinguishing it from International Relations. Despite the promise in the mid 1950s of general systems theory and of Boulding's work and claims, most of the theoretical developments in the study of conflict were not connected into an overarching theoretical framework or systematic research program. The movement remained multi-disciplinary, progressing through small increments on many fronts. . . .
>
> Without a central theoretical core around which to rally, early conflict resolution researchers could not achieve the kind of standardized expertise that is typical of professions and that enables systematic recruitment of new members (Abbott 1988). They continued to have extremely varied backgrounds, training, and career paths that did not converge into a consistent "conflict resolution" outlook. Although they read and published in at least one journal in common (the *JCR*), attended some conferences and had some overlapping memberships in professional societies, their diversity was more striking than

any resemblances. They could not, in effect, vouch for the quality of one another's work according to any recognized standard of excellence in conflict resolution, and, to this extent, the reputation and reward that in part motivate the academic career remained in the hands of the respective disciplines even for those who contributed a portion of their efforts to the movement. (Harty and Modell 1991, 752-53)

In this article, our central interest is to map the flow of intellectual influences through the *JCR* citation network and by doing this, to track the course of this conflict resolution specialty. We use the citations in the first fifteen volumes of the *JCR*, 1957 to 1971. These data were originally collected and analyzed using standard statistical and ethnographic techniques by Harty and Modell. In our reanalysis, we employ a network search algorithm developed by Hummon and Doreian (1989, 1990) to locate a "main path" through a scientific literature.

Network analysts have discovered that citation networks are fruitful data bases for exploring ideas in the sociology of science. While many network analytic approaches can be applied to the study of citation networks, we are using the relatively recent main path approach. It has been demonstrated that this approach can locate connections between the key intellectual developments in scientific fields. In fact, previous analyses of the scientific literature on DNA theory (Hummon and Doreian 1990) and the literature on measures of centrality in social network research (Hummon, Doreian, and Freeman 1990) have discovered quite distinct paths through these citation networks that contain the key intellectual developments in these scientific fields.

In the case of the conflict resolution specialty, our expectation is that the main path technique will locate distinct paths if they exist. Failure to find such paths will support the argument that no overarching theoretical program emerged in this specialty. In fact, based on the work of Harty and Modell, we hypothesized that the pattern of connections in the *JCR* would be amorphous, and would not have a main path that links the development of key ideas in the field. Nevertheless, the characteristics of the discovered paths should document the development of conflict resolution research.

We begin, however, with one note of caution. The citation networks of the DNA and centrality literatures spanned many sources of scientific production, such as multiple journals, research reports, and books. The main path in both literatures traversed not only multiple journals, but also different scientific subfields. The flow of ideas was not bound by a particular specialty or mode of production. Indeed, it is clear in the DNA network, and to a lesser extent in the centrality network, that ideas from other multiple subspecialties merged, enriching the ideas on the main path. In neither instance would one

make the case that at the outset there was a scientific specialty nor that it was focused in one central journal.

In contrast, conflict resolution almost from its inception claimed to be a specific new scientific area focused in one journal. Admittedly, researchers who published in *JCR* also published in *World Politics* and other journals in political science, economics, and psychology. But a central conflict resolution group was determined to publish in the new *JCR*. As in the DNA and centrality literatures, the conflict resolution literature spanned many scientific subfields and was not bound by a single specific method. The difference between these literatures, then, is the initial proclamation that this was to be a separate new field with a central "flagship" journal. It would appear a priori that the citation network of the *JCR* might have a structure quite different from the citation networks in the DNA and centrality literatures. By focusing on one journal we are *decreasing* the likelihood of locating a main "conflict resolution" path that might well exist in the peace research literature more broadly defined.

Data

The *JCR* citation network used for this study spans fifteen volumes and contains 530 citing articles (nodes) which collectively make 7,977 citations.[1] Of these 7,977 citing_author-cited_author pairs[2], 6,337 represent connections from different citing first authors to different cited first authors. In other words, only 1,640 of the 7,977 connections represent a second or third tie between two individuals.[3] Many of these citations are to articles published in other journals or to books. Very few citations are to the same author, let alone the same article. In fact, the 7,977 citations include 3,007 different cited authors.[4] The 530 citing articles were written by 401 different authors.

Citations through Time

Over time, the number of research articles that cited other articles in the *JCR* and the number of citations made by these articles grew (see Table 1). The peak number of articles, forty-nine, occurred in Volume 7. The average number of citations per article, however, was at an all-time low during Volumes 5, 6, and 7. Further, the number of "repeat citations," citations to articles with the same first author, was also at an all-time low during this period. This latter point suggests that the number of effective ties between pairs of people was also at an all-time low during this period. Further, during

TABLE 1
Characteristics of *JCR*a Volumes over Time

Volume	Articles	Citations	Ratio	Citations Minus Repeat Citations	Ratio
1957	1	21	286	13.62	247
1958	2	23	294	12.78	265
1959	3	27	594	22.00	482
1960	4	31	521	16.81	432
1961	5	41	360	8.78	290
1962	6	39	326	8.36	266
1963	7	49	429	8.75	390
1964	8	40	524	13.10	473
1965	9	44	484	11.00	406
1966	10	35	470	13.43	388
1967	11	41	652	15.90	512
1968	12	34	740	21.77	642
1969	13	43	650	15.12	562
1970	14	30	724	24.13	566
1971	15	32	923	28.84	673

a. *JCR = Journal of Conflict Resolution: A Quarterly of Research Relevant to War and Peace.*

the last six volumes, the frequency of citing multiple articles by the same author increased.

The Citation Network

The data base created by Harty and Modell contained about 8,000 citations. The original coding of these citations used different formats for the citing and cited articles. To create a network of citations, we had to merge coding schemes so that a citing article could be recognized as a cited article at a later point in time. Associated with each citation code, Harty and Modell created a listing for the article's author(s). We also know the year of the citing or cited article. Matching on first author and year, we discovered only 260 possible cross-links. We then examined these articles by comparing the remaining authors (if any), and discovered only 232 articles had citing status at one time and cited status at a later time. After considering only these cross-links, we based the remaining network on 7,797 citations.

As noted above, many of these citations involve articles on either the citing or cited side of a citation that appeared only once in the entire data set. To make the network analysis more manageable, we eliminated all such unique articles from the network. This reduction yielded a network of 1,422 articles

(the nodes), with 3,979 citations (the ties) among them. This network is very sparse. Because articles do not cite themselves, and because we assume that there are neither cocitations (a cites b and b cites a) nor citations among articles that appeared in the same year, we calculate that there are 826,932 possible ties. Thus the 3,979 citations represent only 0.48 percent of the possible ties.

The ties in a citation network refer backward in time (a cites b). To understand the development of a field, we chose to study the influences forward through time (b is_cited_by a). To do this, we transposed the citation network. This approach made it consistent with networks studied in earlier work using main path analysis, which examines the flow of contributions to a field as they converge or dissipate through time.

Methods

Network Search Algorithms and Exhaustive Trees

Main path analysis has two steps. In the first step we compute the exhaustive search tree for each node in the network. Each tree contains the set of all possible paths emanating from a node. We do this by using the exhaustive search algorithm described in Sedgewick (1983). We then iterate over all these exhaustive trees and count the number of times we find each citation (a tie in the network). This produces a valued network, where the tie values are the total frequencies for a tie cumulated over all exhaustive search trees.

Main Path Analysis

In the second step of main path analysis, we trace a path through the valued network from node to node, always choosing as the next tie (and so, the next node) that tie with the highest frequency leaving that node. Specifically, from any starting node, we choose the outgoing tie that has the highest value, and move to the next node. We continue until we reach a terminal node, one with no ties leaving it. This sequence of choices traces a path through the network for a given starting node. This path, this sequence of "visited" articles, is a "main path." If we apply this priority search to every node, we generate the list of all main paths through the network. The details of implementing these techniques are discussed in Hummon and Doreian (1990).

There are two additional statistics of particular importance for analysis of these data—tie frequency and endpoint frequency. Tie frequency is the count, over the set of all main paths, of the number of times each tie (i.e., citing_
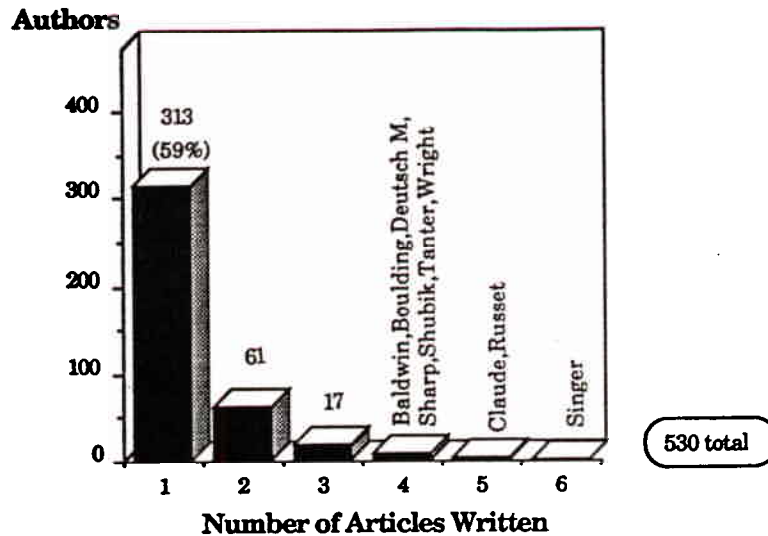
Figure 1:Distribution of Authors

author-cited_author pair) is part of a main path. Endpoint frequency for an article is the number of main paths that terminate in that particular article.

Results

In-Degree and Out-Degree Analysis

We first examine the in-degree and out-degree vectors for the *JCR* citation network. These are standard measures for identifying the major contributors in a citation network.

The distribution of number of *JCR* articles per author is shown in Figure 1. The authors writing the most articles are: D. Baldwin (4), K. Boulding (4), M. Deutsch (4), G. Sharp (4), M. Shubik (4), R. Tanter (4), Q. Wright (4), B. Russett (5), I. Claude (5), and J. D. Singer (6). The distribution of the number of times each author is cited is shown in Figure 2. The Top 10 cited authors are: L. Richardson (48), K. Boulding (49), K. Deutsch (52), R. Snyder (55), V. Bixenstine (55), Q. Wright (83), J.D. Singer (83), T. Schelling (97), A. Rapoport (121), and M. Deutsch (123). Combining the results in Table 1 with the pattern in these distributions, we see that participation in this emerging discipline was a "one-shot affair" for the vast majority of authors,
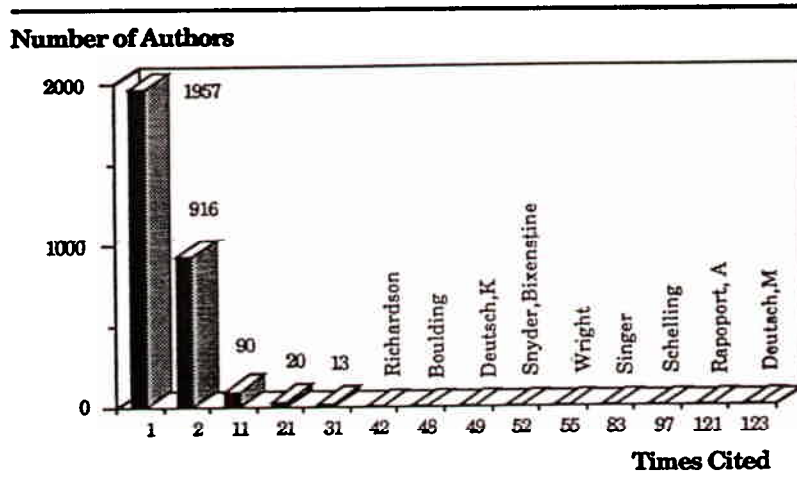
Number of Authors

Figure 2:   Distribution of Citations

both citing and cited. This is not what we would expect to find if the emerging specialty was becoming a coherent intellectual field. Moreover, as was previously noted, the citation network is extremely sparse, indicating the limited extent to which intellectual contributions were passed on from one scientific production to the next.

Main Path Results

We applied the main path technique to the *JCR* citation data. The results contrast sharply with those obtained when the main path technique was applied to other scientific literatures—specifically the analysis of the development of DNA and network centrality. The DNA network has a single main path in which the most important link involves the 25 April 1953 paper in *Nature* by J. D. Watson and F.H.C. Crick. The centrality literature also has a single main path which originates with work by Bavelas and terminates with that by Freeman. In both cases, a single main path contains the key intellectual developments in the field and work by the acclaimed founders appears on the main path. Moreover, this important main path spans the entire time period and does not "leap over" multiple years. In other words, the main paths in these other studies of successful fields suggest that the scientific developments were not only cumulative but the increments were also slow and steady.

In contrast there is no single main path, or even a small set of main paths, in the *JCR* citation network. In the field of conflict resolution, we find
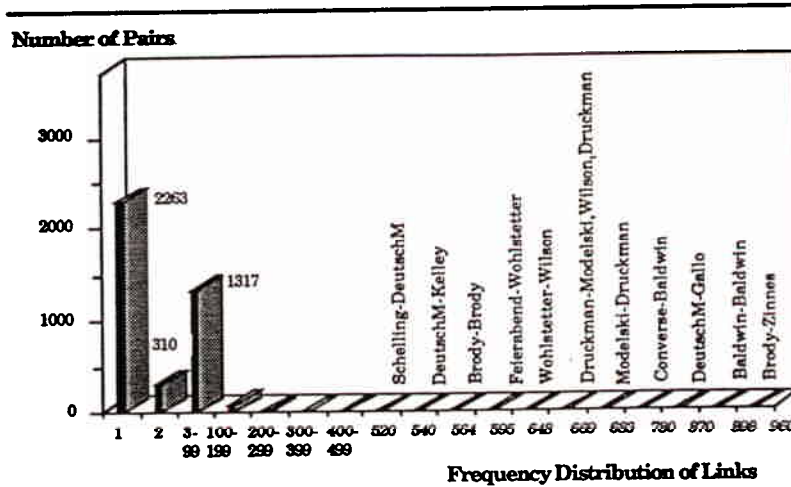
Number of Pairs

Figure 3:   Distribution of Citation Pairs

multiple main paths. In a sense, in the *JCR* citation network, for most articles, each article typically generates a different main path. The founders of the conflict resolution field, such as Boulding, Angell, and Wright, are conspicuous by their absence from all main paths; few main paths span the entire time period; and all have large leaps over multiple years.

Citation Pairs and Endpoints in Main Paths

Figure 3 presents the distribution of tie frequencies for the citation pairs (ties) in the set of all main paths. Figure 4 presents the distribution of endpoint frequencies for the terminal articles for the set of all main paths. What is interesting about both these figures is that, for the most part, they contain a different set of names than we see in the in-degree, out-degree analysis of Figures 1 and 2. The primary exceptions are T. Schelling and M. Deutsch. Thus the most frequent links in the set of all main paths through the *JCR* network identify a different group of scholars than simple citation count measures.

The Meta-Main Path

Because there is no a priori way of choosing between the multiple main paths, we provided focus for our analysis by creating a meta-main path such that each tie in this metanetwork had a tie frequency of at least 200 across all
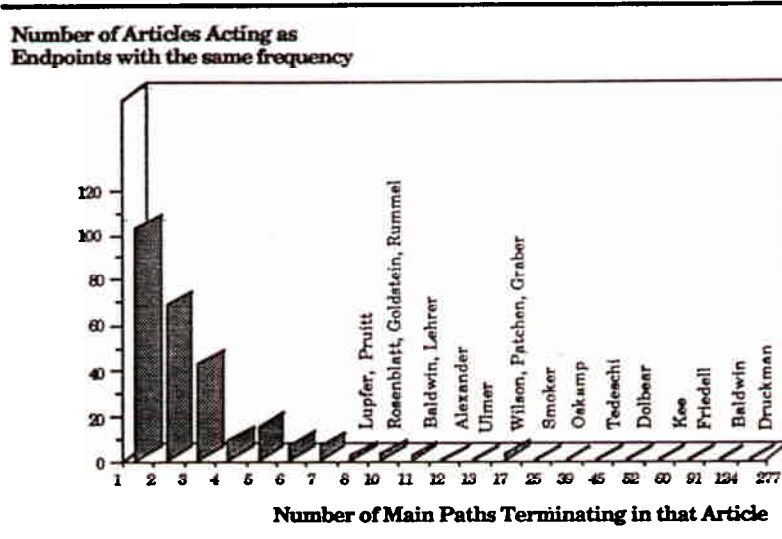
Figure 4: Distribution of Endpoints

the different main paths. The meta-main path can be thought of as a composite picture representing that portion of all main paths that are similar and that have strong tie strength. (If all main paths were identical and if all ties in these main paths had a tie frequency of at least 200, then there would effectively be a single main path and that main path would be the same as the meta-main path.) Figure 5 shows the meta-main path for the *JCR* network. In this figure, the width of the line indicates its frequency. For example, the Brody-63 to Zinnes-68 link has the highest traversal count (960) in the valued network used to determine the separate main paths. The ties are displayed chronologically in Figure 5 with the earliest articles at the bottom, and the terminal articles in 1971 at the top. Figure 5 shows a path that begins in 1957 and terminates in 1971, with many initiating and terminating articles and multiple interceding articles. This result suggests that although science is being conducted in a cumulative fashion there is little agreement on the exact influence path. Thus, at any point in time, the researchers in this area could not point to a single influencing article but only to a relatively large group of influential articles. In addition, Figure 5 shows a set of disjoint main paths, which suggests that there were multiple paradigmatic approaches in the conflict resolution movement. The dream of the movement's founders, the emergence of a cross-disciplinary theory of conflict resolution, was not coming true.
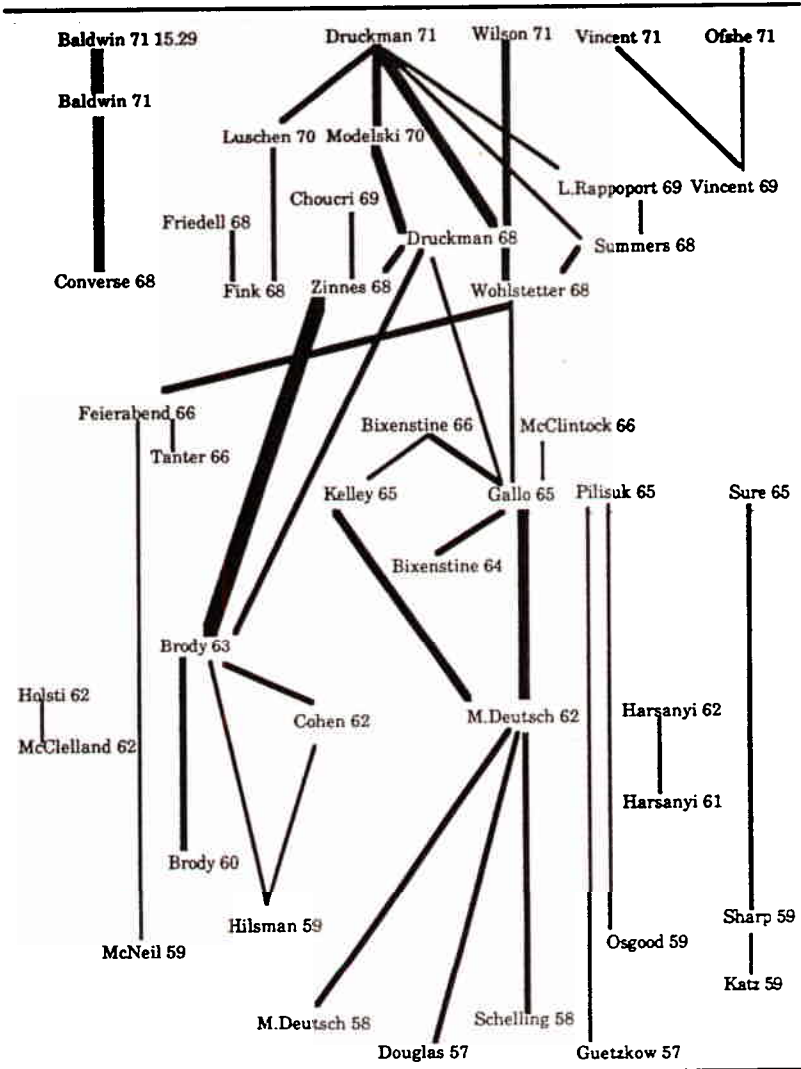
Figure 5:   Strong Modal Influence Paths

We explored this suggestion by examining the less frequent ties. Specifically, we added to Figure 5, for each pair of articles, any tie regardless of its tie frequency. The result was a completely connected meta-main path (Figure 6). It turns out that none of the new ties have a frequency less than 100.
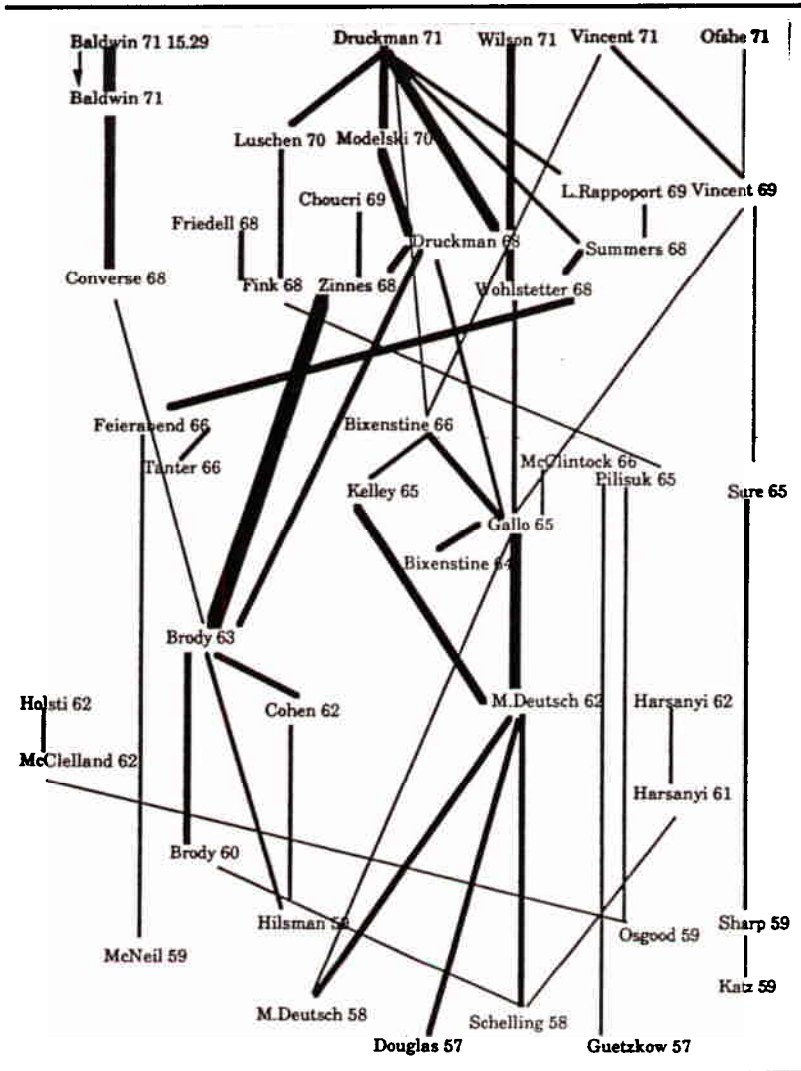
Figure 6:   Fully Connected Influence Paths

Figure 6 shows that articles cross main paths in their influence. For example, in Figure 6 we see that the Schelling-58 article, which is a primary originating article in the path running up through the middle of Figure 5, also contributes to the development of the alternate paths that follow from Brody-60 and

Harsanyi-61. This result suggests that there was some unity, although at a fairly weak level, in the conflict resolution research, that is, the research paradigms did, at least to a limited extent, overlap.

Not all ties that actually occur in the meta-main path are, from a probabilistic standpoint, equally likely to have occurred; that is, for each tie there is a theoretical maximum number of main paths that might contain that tie. The lower the theoretical maximum, the less likely it is for this tie to be observed. We can use these theoretical maximum values to weight the observed data to determine whether the ties that we observe as most frequent are actually more likely than less frequent paths.

Given a few assumptions, we can calculate the theoretical maximum number of main paths that might contain a particular tie. These assumptions are: (1) all possible paths are equally likely; (2) citations only go forward in time, thus citations from 58 to 61 are disallowed as are citations from 61 to 61; and (3) there are no citation loops, that is if article a cites article b then article b does not cite article a. Under these assumptions, the theoretical maximum number of main paths that contain a tie from year X_i to X_j depends only on the number of articles published in the preceding and subsequent years. Let us define N_i as the number of articles in year i, and Y as the last year. Then the theoretical maximum number of main paths that contain tie X_i (citing) to X_j (cited) is:

$$\prod_{k-1}^{j=1} N_k * \prod_{k=i+1}^{Y} N_k.$$

Several things are important to note here. First, all ties of the same period (i.e., where the citing article occurs in year X_i and the cited article occurs in year X_j) have the same maximum. Second, those ties that skip years are less likely (have a lower maximum). Third, citations within the same year (e.g., from 61 to 61) and citation loops, had they been included, would have increased the theoretical maximum to infinity. Fourth, in actually calculating the theoretical maximums for this article we approximate the number of articles in each year by the number of articles published in *JCR* during that year which cited at least one other article.

Figure 7 redisplays the meta-main path from Figure 5 with each tie now weighted by the theoretical maximum for that tie. To weight each tie, we divided the tie's frequency by the theoretical maximum for ties of that period. Then we take the log base 10 of this value. In Figure 7, the width of each line corresponds to the logged value. The larger the value, the wider the line. A change in line widths corresponds to a factor of 10. In this figure, the values go from −19 (e.g., the Baldwin-71 to Baldwin-71 tie) to −7 (e.g., the
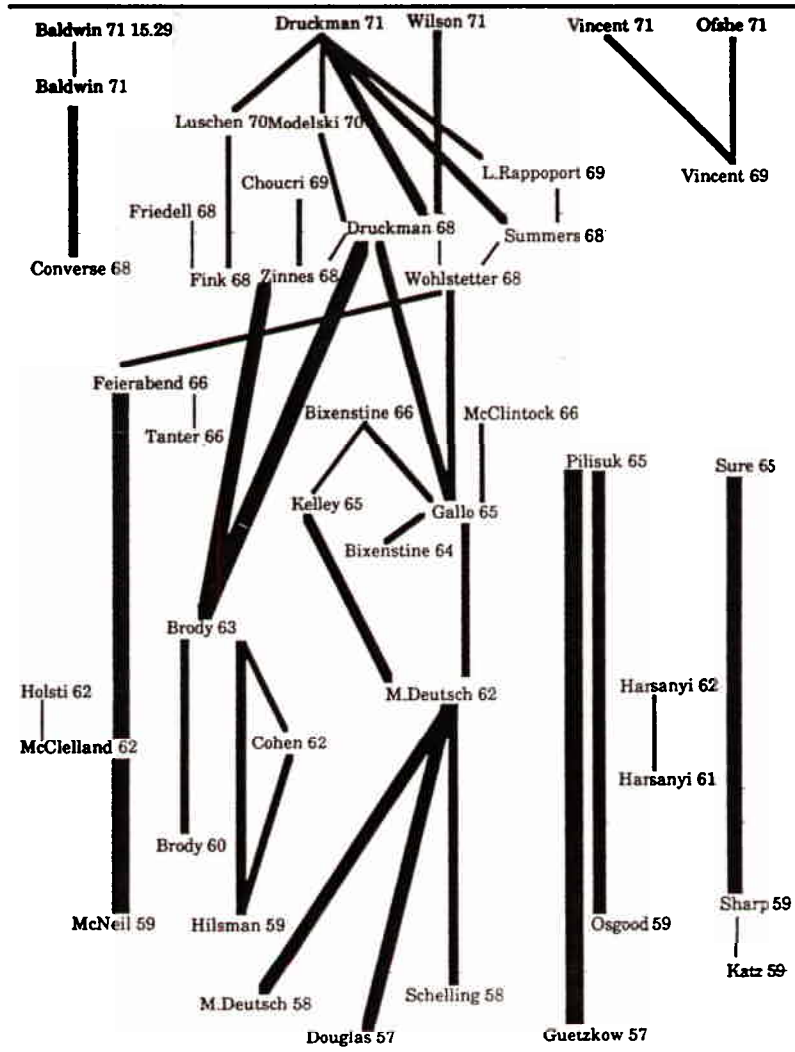
Figure 7:   Weighted Modal Influence Paths

Guetzkow-57 to Pilisuk-65 tie). Contrasting Figures 5 and 7, we see that by weighting the articles, the central path is now, on the whole, much so stronger. Thus this path is not only frequent but also frequent relative to what it would have been by chance. Throughout the rest of this article, Figure 7 will be used as our meta-main path figure.

One feature of Figure 7 is especially noteworthy. Articles on any meta-main path tend to occur either during the late 1950s or during the late 1960s and early 1970s. There are relatively few articles on the path that appeared in the mid-1960s. Moreover, these middle years are not only leaped over, but leaped over by very strong ties. These "leaps" not only occurred, but also occurred frequently, and were quite unlikely to occur this frequently.

The differences observed across time periods correspond to developmental periods Harty and Modell identified in their historical analysis. Harty and Modell examined the numbers and types of articles published in the *JCR* as well as some characteristics of their citation patterns, finding evidence for three relatively distinct periods in the first 15 volumes (differences were seen, for example, in the proportions of articles dealing solely with conflict at the international level, articles dealing with several levels of conflict—an indicator of interdisciplinarity—and articles dealing with game theoretic analyses of conflict). The three periods were given names that described their institutional flavor, as reported by participants—1957-1960, the Pioneer Years; 1961-1966, the Golden Years; and 1967-1971, the Dissolution Years.

The pattern of the meta-main path in Figures 5, 6, and 7 fits this description quite well, albeit with several alternative interpretations for the three periods. To better understand the meta-main path results, we need to present more information from Harty and Modell concerning these three periods.

Harty and Modell's Analysis

Harty and Modell labeled 1957 to 1960 the *Pioneer Years*. During this period, the leaders of the conflict resolution movement founded the *JCR* and established the Center for Research on Conflict Resolution at the University of Michigan (CRCR). The "flavor" of the times, according to Harty and Modell was strongly interdisciplinary.

Figure 8 displays those authors discussed by Harty and Modell as important in the conflict resolution specialty during the Pioneer Years. Clearly, this is a distinguished group of academics, associated with the major research universities in the country (see histogram). The asterisks indicate the only two members of this group of distinguished pioneers who contributed articles to the meta-main path in the *JCR* citation network: Schelling and Guetzkow. Many of the "founders" of the new field did not contribute to the meta-main path, including Boulding, Angell, Singer, A. Rapoport, and Wright.

Harty and Modell labeled the period 1961 to 1966 the *Golden Years*. These years saw a flurry of peace-related academic and political activity, including the first International Arms Control Conference, establishment of new journals, and calls for a new disciplinary base of "peace research," and introduc-
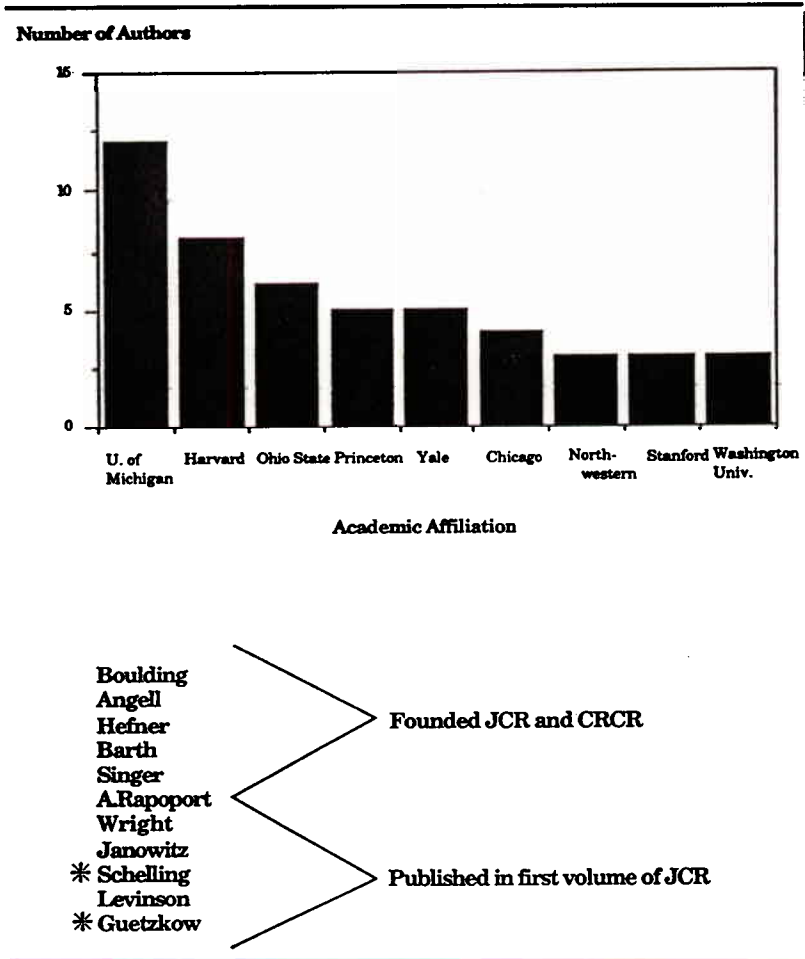
Number of Authors

Academic Affiliation

Figure 8:   The Pioneer Years
SOURCE: Harty and Modell (1991).

tion of new intellectual tools, including game theory, in the scholarly work and articles of the emerging conflict resolution specialty.

During the Golden Years, a new group of authors appear as important figures in Harty and Modell's historical account. Table 2 presents this list. Again, however, not all of these authors show up on the meta-main path, notably K. Deutsch, who received numerous citations.

Finally, Harty and Modell call 1966 to 1971 the *Dissolution Years*. The Center for Research on Conflict Resolution closed, the *JCR* moved to Yale

TABLE 2
Golden Years

Pioneers	New Characters	
Boulding	*Sharp	*McClelland
Angell	Snyder	Kelman
Hefner	Pruitt	*Katz
Singer	*McNeil	Benoit
A. Rapoport	Richardson	K. Deutsch
*Schelling	*Brody	*M. Deutsch
	Oskamp	*Bixenstine
		*Pilisuk

SOURCE: Harty and Modell (1991).
NOTE: The asterisks indicate the authors who contributed articles to the meta-main path in the *Journal of Conflict Resolution* citation network.

TABLE 3
Dissolution Years

Pioneers	Golden Years	New Characters
Boulding	*McClelland	Porter
Hefner	Snyder	*Fink
Barth	*Pilisuk	*Converse
Singer		Bernard
A. Rapoport		Mack
		*Osgood

SOURCE: Harty and Modell (1991).
NOTE: The asterisks indicate the authors who contributed articles to the meta-main path in the *Journal of Conflict Resolution* citation network.

University and became part of a traditional International Relations department, and a game theory party split off from the movement into its own journals (*Simulations and Games* appeared in 1970; *The International Journal of Game Theory* in 1971). Table 3 shows the cast of characters identified by Harty and Modell as important during this period, and again few of them fall on the meta-main path. During this period, the interdisciplinary focus on a general theory of conflict appears to have been breaking down.

Clearly those people identified as being important to the field by Harty and Modell are very different from those identified as influential through main path analysis. The historical analysis relies on overall institutional factors, or external factors, such as who ran the Conflict Resolution Research Center or acted as editors of *JCR*, as well as on simple citation counts. Our

analysis, on the other hand, focuses exclusively on scholarly influence as determined through the citation network. The fact that the groups of people identified as influential are so different suggests that in the development of the conflict resolution movement there was a big difference between those who "talked" about what was needed (institution builders) and those who "acted" by producing new science (idea builders). Or, as Harty and Modell (1991) put it,

> [T]heoretical, empirical, and methodological ambitions and developments in the new scientific enterprise, as well as its drive for interdisciplinarity ... constitute the *internal* aspects of the movement's development. The institutional and financial arrangements, the foundations of professional careers, the effects of political activity and developments, and the struggle to establish authoritative applications of theoretical results are among the *external* factors that affected the outcome of the first conflict resolution movement. (P. 722)

Figure 9 describes the level of scholarly activity in the *JCR* broken down by the three periods. What is most striking is that although the Golden Years witnessed the *highest* level of article *production*, the period had the *lowest* rate of the *citations* per article. Thus, while much was written, the authors of this period were less concerned than those before or after them with citing others. Because cross-disciplinary research is often characterized by *high* levels of citation, this lack suggests that although much work was being done in the new conflict resolution specialty, little of it was truly building on a cross-disciplinary base. Further, the low rate of citations per article suggests a decreased interest in carrying forward earlier lines of research. Part of the low citation rate may well be attributable to an increase in speculative and/or nonscholarly articles. Harty and Modell (1991) made some observations about the journal's contents in the Golden Years that are suggestive in this regard:

> In this period, work that dealt explicitly with international peace was at a high —almost one in every four articles—a proportion more than thrice that in the pioneer years, and over eight times that in the succeeding era, when the peace focus of the conflict resolution movement had nearly disappeared. (P. 738)

Among these articles on international peace, reviews (including book reviews) were especially common, representing almost three-tenths of the articles. Further, many of the articles were calls for interdisciplinary research and a large number of the remaining articles were case studies.

As shown in Figure 7, although much was published during the Golden Years, little of it was picked up by subsequent authors in the form of scientific citations. In the meta-main path in Figure 7, many of the paths leap over the Golden Years, with few or no key articles occurring during this period. Thus

Articles per Period

Pioneer
Years
18.99%

Dissolution
Years
34.11%

Golden
Years
46.90%

Cites per Period

Pioneer
Years
21.25%

Dissolution
Years
46.25%

Golden
Years
32.51%

Cites per Article

Pioneer
Years

Golden
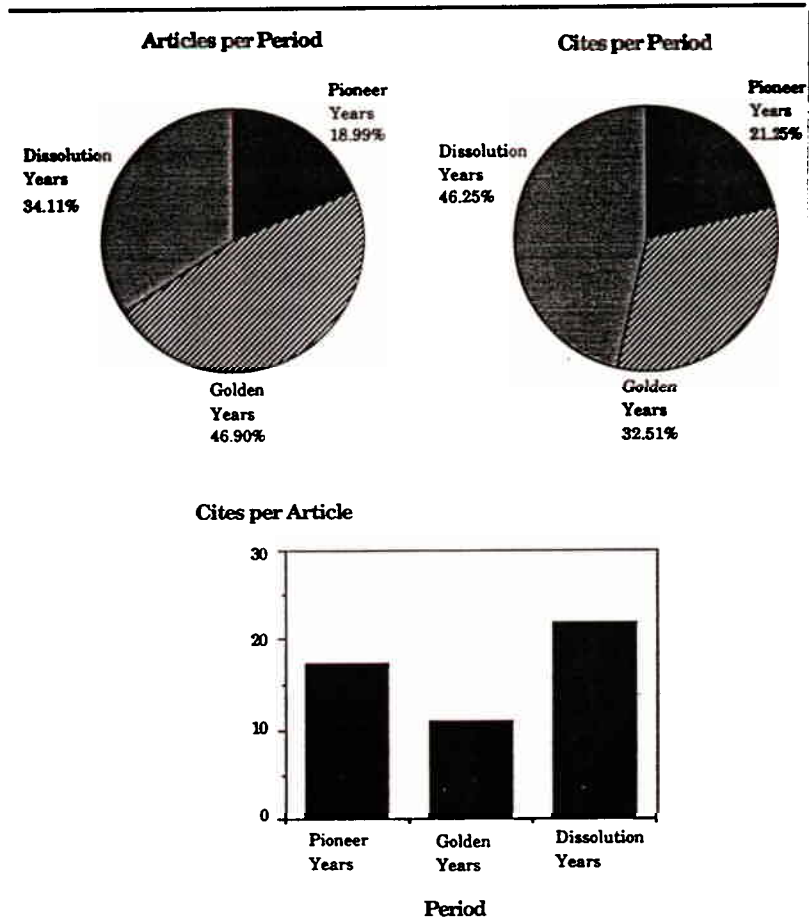Years

Dissolution
Years

Period

Figure 9:   Articles and Cites per Period

low citation style may have contributed indirectly to the fact that this Golden Years work is rarely cited by later work. That is, while such low citation style may indicate an intellectual movement to new ideas, it also tends to break off communication about connections with near intellectual neighbors, perhaps reducing their interest in the work (Kaufer and Carley 1993).

One alternative explanation would simply be that *JCR* promoted avant garde research during the Golden Years, giving birth to much work that is now carried on in traditional, mainstream journals. In that case, work of the Golden Years would be expected to be picked up and cited heavily in the

other political science and international relations journals rather than within *JCR*. Although we have not thoroughly explored this alternative, it is doubtful that this explanation holds. For the articles in the meta-main path in Figure 7 during the Golden Years, few of the authors can be identified as founders of new subfields. Harty and Modell (1991) observe that

> although the middle years of the movement were "golden" in the sense of proliferation of interesting material, they apparently did little to move the science qua science toward a point where it might be institutionalized, that is, where it could boast a generally accepted theoretical framework that would serve as a focus for professional practice and degree programs. (P. 740)

The term Dissolution Years was given to the last period by Harty and Modell. We found that during this period of dissolution there was an increase in number of citations per article and a high frequency in citing multiple articles by the same author. Such citation statistics may seem at odds with the concept of dissolution. Dissolution is attributable not to a decrease in citation but to a failure of a particular pattern of citations to emerge. More specifically, and as we will discuss in more detail below, dissolution is attributable to a failure in the emergence of interdisciplinary research.

Figure 10 summarizes the combination of the results of the historical and the meta-main path analyses. It presents the meta-main path diagram of Figure 7 with the articles annotated by whether they are frequent authors in the *JCR* (squares) and whether they are frequently cited (circles). Also, the numbers adjacent to the articles in the diagram indicate in what period an author was identified by Harty and Modell as playing an important role. Thus, Deutsch-62 is frequently cited, Deutsch frequently contributes articles to the *JCR*, and Deutsch was identified by Harty and Modell as important during period 2 (the Golden Years). In addition, we have placed a horizontal line indicating the end of the Pioneer Years and beginning of the Golden Years and another at the end of the Golden Years and the beginning of the Dissolution Years. The most striking feature of Figure 10, however, is that most of the articles on the meta-main path would never have been identified by simple citation counts or by historical methods focusing on institutional influence. Of the forty-four articles displayed in the meta-main path, only sixteen were either cited frequently by authors who wrote frequently for *JCR*, or were cited by authors identified by Harty and Modell as important.

The Search for Interdisciplinarity

The question still remains, to what extent was the work truly interdisciplinary. As previously noted, the lack of a single main path suggests that a
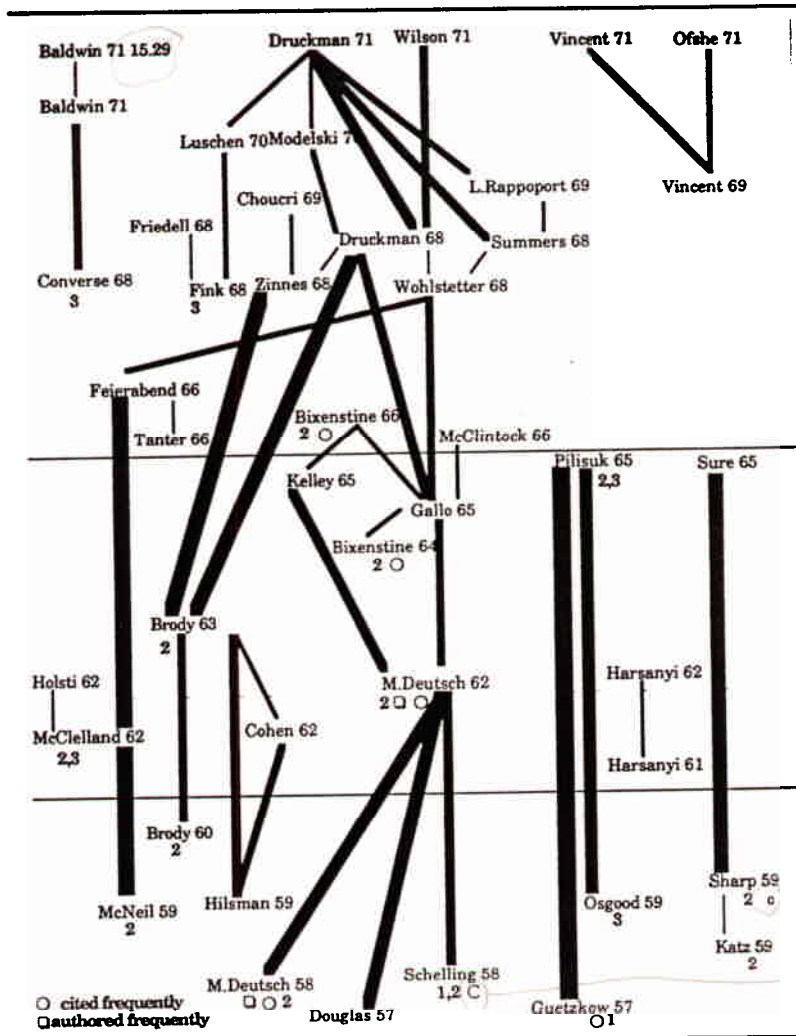
Figure 10:   Annotated Meta-Main Paths

new movement built on an interdisciplinary basis was not emerging. To further address the issue of interdisciplinarity, we now consider the scientific field of the authors of each of the articles in the meta-main path. If each of the separable strands of research displayed in the meta-main path is built by researchers in multiple disciplines, then this would indicate that the work is truly interdisciplinary. In contrast, if these strands of research break down
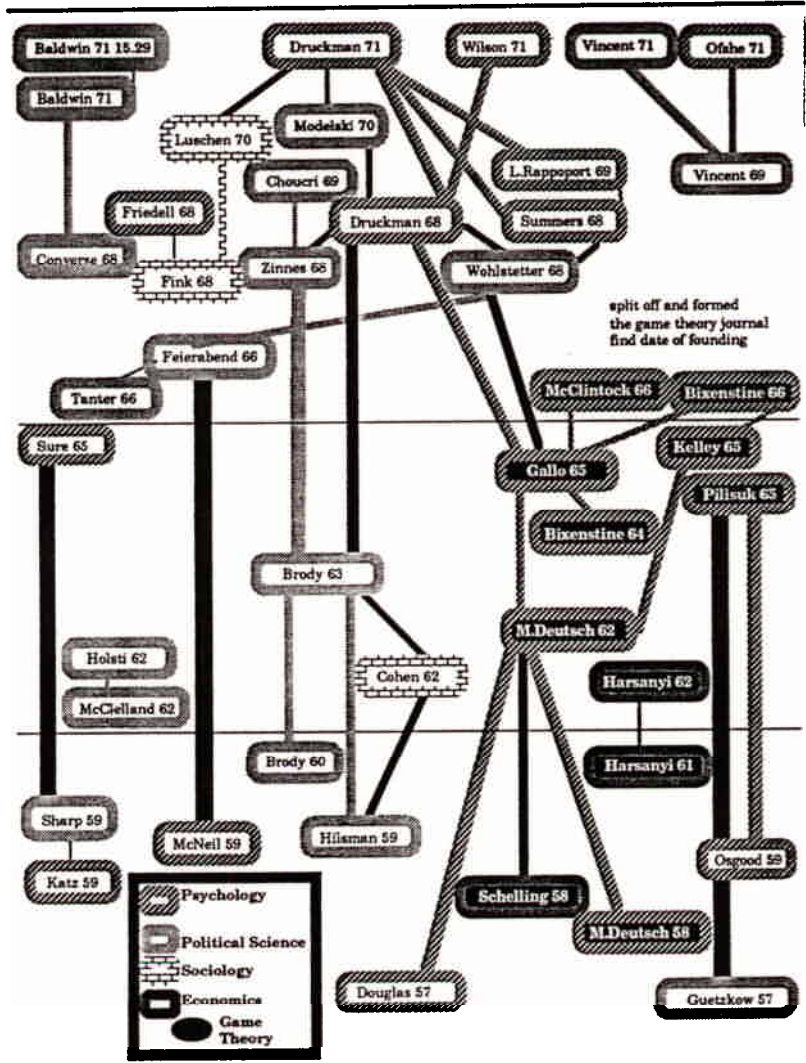
Figure 11:   Meta-Main Paths with Subfield Specialties

along disciplinary lines, both in the fields of the authors and the fields they drew on, this would indicate a lack of true interdisciplinarity.

Figure 11 presents the meta-main path annotated with the substantive scientific fields of the authors, and with whether they took a game-theoretic

approach. Four fields are marked—political science (members of which are predominantly drawn from the subfield of international relations), psychology (members of which are predominantly social psychologists), sociology, and economics. Of the forty-four articles in the meta-main path, eighteen fall in the political science area, twenty in psychology, three in sociology, and three in economics. Twelve of the forty-four utilized game theory.

Overall, the two main strands—political science and psychology—remained fairly distinct in their contributions through the fifteen-year period. Even the most merged central branch has one subbranch (left) that is primarily in political science, and the other subbranch (right) that is primarily psychology. In addition, the psychology subbranch is further connected by a common methodological context—game theory. As a further support for the argument that the strongest links are methodological, we note that all of the economists on the meta-main path are game theorists. In the Pioneer Years there was clearly an interdisciplinary flavor in that the major articles on the meta-main path are drawn from three disciplines. However, the hoped-for interdisciplinarity did not flourish, particularly in the Golden Years, as the next most influential work is typically of the same disciplinary type as its influential predecessor. In the end, the *JCR* reverted to its dominant international relations core, and the game theorists split off and formed their own journals. The experimentalists (drawn primarily from psychology) remained separate throughout all periods.

In addition to this analysis of the meta-main path, we were able to code the primary discipline of most authors on the thirty-two main paths.[5] Figure 12 presents a star plot of the disciplinary coding of the main paths. This is a star plot with four dimensions: psychology, political science, economics, and sociology. Each point of a star is associated with one of these dimensions. The star, if fully formed, would appear as a diamond (a square tilted on its side). The length of each point from the center of the star is proportional to the number of articles in that main path from that discipline. Where successive star points exist, they are connected to fill out the edge of the star.

A striking feature of Figure 12 is that few of the stars look like diamonds. In fact, many of the main paths incorporate only one discipline, thus they appear as simply a line. Eight of the stars involve only psychology (a vertical line at 12:00); nine include only political science (a line at 3:00). In fact, only two main paths are complex, involving the disciplines of psychology, political science, economics, and sociology. This pattern suggests that the main paths in the *JCR* literature are disciplinary, rather than integrated perspectives from several disciplines.
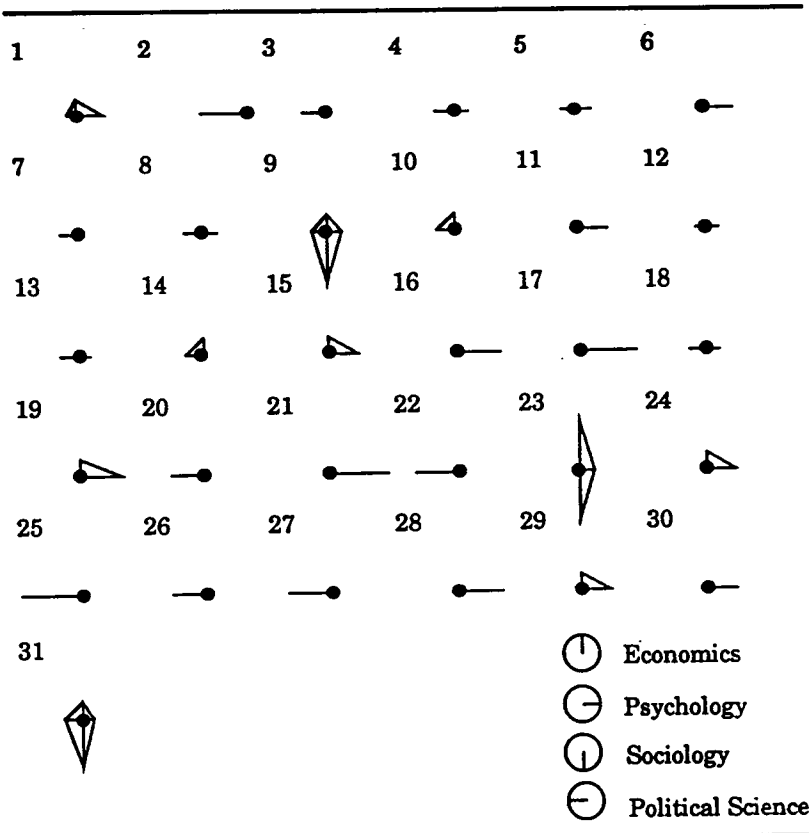
Figure 12:   Star Plots for Each Main Path

Discussion

Both the historical approach followed by Harty and Modell and the main path analysis presented in this article suggest that true interdisciplinarity did not emerge in the first conflict resolution movement. At a more detailed level, the two analyses provide different perspectives on the meaning of the Golden Years.

Harty and Modell interpreted the Golden Years (from 1961 to 1965) as a period rich with intellectual ferment, political activity, fund-raising efforts, and growth in peace research. It was a period that initiated many newcomers to the specialties of conflict resolution and peace research. They were buoyed

by a general upsurge of interest in the social sciences, and the widespread desire to apply social science to important real world problems. These were certainly heady times for most social scientists, a period of institution building.

Our structural analysis develops a different image. This period contributed relatively little to the intellectual developments that followed. Indeed, authors writing in the later period were quite likely to build on work written in the earliest period. Of the many scientists and scholars recruited to the conflict resolution specialty during this middle period, most did not maintain interest. The overall citation pattern is consistent with a "soapbox" process where an author from "outside" writes a single piece which is published in the *JCR*. That author never returns to the intellectual fray of conflict resolution to defend or further develop his or her ideas. Most of the contributions, particularly during the Golden Years, were never used by others in the movement. The structural evidence suggests that rather than consolidating the developments started in the Pioneer Years, the Golden Years dissipated earlier gains, and lead directly to the outcome of the Dissolution Years. From an intellectual standpoint, the Golden Years were *not* idea building. This follows from the hypothesized incoherence of the field—for only in a coherent field would the most consistently conspicuous authors be the inspiration of a consistent line of thought, rather than the distant ancestors of a number of discrete (and usually "false") starts.

Our conclusion is that the Golden Years were a period of institution building but not of theory building. Restivo (1990) argues the following:

> Total immersion in, commitment to, and subordination to an organization, institution, or community undermines objectivity—even if the organization, institution, or community is oriented to goals of discovery and explanation. On the other hand, an extremely weak coupling of individual and collectivity will isolate the self and undermine the ability of the individual to communicate with others. (P. 124)

Applying this view to the conflict resolution specialty suggests a movement from a period of institutional foundation (the Pioneer Years) to a period of institutional immersion (the Golden Years). During the Pioneer Years, there were necessarily weak links between individuals and the conflict resolution community as the community was still amorphous, still in the process of being defined. One consequence was the low level of cross-citation within this period—each author felt himself to be a prophet crying in the wilderness. As the founders of the Michigan Center and the early editors of the journal mobilized organizational and cultural resources, however limited, they provided the organizational basis that was necessary for the emergence of the

conflict resolution community. By the Golden Years, this community was established and externally recognized. But the ideological commitment of many of the authors to the movement, their immersion within it, resulted in a lack of "objectivity" (to use Restivo's term) which is exemplified by the lack of citations in their work.

There are of course many possible consensual epistemological bases besides objectivity, but the lack of citations in the period suggests that *none* of the possible bases for building intellectual fields was present. This lack of a shared basis for consensus around such significant issues as what constitutes good work (whether or not the basis would have been some sort of objectivity) may ultimately have led to the dissolution of the movement—at least as it was initially conceived and directed to the goal of building a general theory. Whether a similar phase of "lack of a consensual base" has occurred in the emergence of other new fields, and under which conditions it leads to their dissolution, is a point worthy of further investigation.

The conflict resolution community never became a community in the strong sense. The members in general failed to form an "invisible college" (Crane 1972)—although the subcommunity of game theorists did. As previously noted, the differences between the individuals were more striking than their similarities. The field's authors were united by a journal, but not by shared conferences, institutions, or other organizational units that promote face-to-face interaction. Moreover, the individuals were divided in their basic paradigms, a fact evidenced by the low level of citations between articles within the journal, and by the lack of a main path. The failure of conflict resolution to form a new invisible college is at least a partial cause of the original movement's ultimate dissolution. The causal contributions of the lack of an invisible college and the lack of a consensual base during the Golden Years cannot be measured on the basis of this single case study, but both factors appear to have played important roles in the fate of the first conflict resolution movement.

This study, like that of Harty and Modell, truncates its analysis at Volume 15. Institutionally, and historically, this volume marks a turning point (*JCR* moved from Michigan to Yale) and so a natural end to the study. The question remains, however, would the history be rewritten if further volumes had been considered, and if the field actually began to cohere in particular ways? The simple answer is no. First, additional volumes, unless they contained massive cites to articles in the Golden Years, would primarily serve to increase the strength of ties that leap over the Golden Years. Second, the main path analysis demonstrates that, during the Dissolution Years, game theory became somewhat less prominent, and there were still multiple distinct intel-

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lectual paths (see Figure 11). Thus there is substantive agreement between
the historical and main path analyses about the dissolution occurring toward
the end of the period studied. Such agreement across methodologies argues
against later volumes altering this view. And third, should a coherence
emerge in later volumes, this would not necessarily indicate the reemergence
of the conflict resolution movement, but instead, depending on which articles
were in the ultimate path(s), might indicate the emergence of yet a new
subfield.

Two final methodological points are worth mentioning. First, in this analy-
sis we focused on a single journal. In the case of conflict resolution identify-
ing a subfield with a flagship journal made sense. For other fields this same
identification may not make sense. Researchers seeking to apply the main
path technique to other fields should decide whether to make a subfield-jour-
nal identification on the basis of the historical and institutional evidence for
that subfield. Second, we applied the main path technique to a network
composed of 3,979 ties, each of which represented an article to article tie.
The main path technique is designed to examine a network in which time
provides a directionality to the links and each node represents a distinct event
in time. This technique could not have been applied to a network of authors,
for authors, unlike articles, do not appear at a single point in time. A standard
network analysis of the ties between authors, if done in addition to this main
path analysis, might have provided additional insight into the roles that
scientists can and do play in the development of scientific specialties. Future
researchers might consider utilizing both structural techniques.

Conclusions

The main path technique has proven useful in understanding the develop-
ment of scientific fields. Specifically, main path diagrams map the intellec-
tual influences and cross-fertilizations that are so important to cumulative
scientific progress. As a scientific procedure, combining structural tech-
niques like main path analysis with historical procedures, as was done in this
article provides a richer, more detailed understanding of a historical period.

Historical analysis has the advantage that it can locate and describe insti-
tutional contexts. Structural analysis of historical data such as main path
analysis has the advantage of controlling for the powerful influence of insti-
tutional context. We suspect that anyone examining the historical record of
the development of conflict resolution research would be impressed by the
distinguished group of academics and the prominent universities who were
early participants in the movement. It is easy to conclude that important

academics at major universities are the intellectual prime movers in a scholarly field. Our research, by combining the two methodologies, throws doubts on this viewpoint by highlighting the importance of work by individuals who were less institutionally prominent during times of social change (such as Kelley, Douglas, and Druckman in this analysis).

On a more theoretical note, we observe that scientific influence is not only a matter of popularity. Simple popularity measures like citation counts do not necessarily agree with the results of analysis identifying the main path of intellectual developments. It has been suggested that popularity (high citation) is at least partially a function of obligatory citing of institutionally important people (Carley 1990). The present study tends to support this suggestion and also to show that scientific influence is something quite different. Indeed, scientific influence appears to be a matter of setting forth ideas at a certain level of formalism. In general, the articles in the meta-main path tend to be either review articles (relatively few) or articles setting out general models. In the conflict resolution literature, the general model articles tend to represent modeling approaches in international relations, mathematics and game theory, and the experimental paradigm in psychology. We also observe that the meta-main path articles tend to deal with important research questions, not specific problems. In contrast, the more popular articles and books that are conspicuous by their absence from the main path tend to operate at the "grand theory" level. These popular works are cited and are inspiring as they suggest ways of conceptualizing an issue. Unlike the more formal works that appear in the meta-main path, however, they do not provide a solid bedrock on which succeeding scholars can build in a strongly cumulative fashion.

Notes

1. This represents the set of research articles that cite other articles as originally coded by Harty and Modell (1991).

2. For the cited authors, there was a small loss in information. Information on the cited author includes author name(s) and year. If an author(s) wrote more than one article in a year, information as to which specific article(s) was cited was not kept. Thus all citations to the same author(s) for works published in the same year are combined. This reduces, albeit very slightly, the number of citing_author-cited_author pairs, and will in the ensuing analysis slightly increase the links to cited_authors who published two or more articles in the same year. This should increase the probability of finding a main path.

3. If second or third authors are considered, the number of second and third ties between individuals goes up slightly. Nevertheless, it is still the case that the vast majority of citations are to others rather than to self.

4. All nonpersons cited, such as commission reports, are deleted, as are all authors whose names were incomplete in Harty and Modell's data (1989). The term *author*, as used here, refers to the first author of an article. Thus the following five examples contain only three authors—Morris, James, and Colby: (1) Morris, Herman, and Melvits; (2) Morris; (3) James and Colby; (4) Colby and James; (5) James and Colby.

   5. We have no disciplinary data for one main path.

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KATHLEEN M. CARLEY is Associate Professor of Sociology in the Department of Social and Decision Sciences at Carnegie Mellon University. She is interested in the cognitive basis for social behavior, especially as it relates to the diffusion of information and organizational performance.

NORMAN P. HUMMON is Professor of Sociology in the Department of Sociology at the University of Pittsburgh. His research interests include technology and organization, models of scientific development, and computer applications in the social sciences.

MARTA HARTY is Lecturer in the Department of Philosophy and Research Associate in the Center for Advancement of Applied Ethics at Carnegie Mellon University. She is interested in alternative dispute resolution and is actively involved with the Pittsburgh Mediation Center.