Research Interactivity in Cognitive Science:
A Bibliometric Analysis of Interdisciplinarity

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Research Interactivity of Cognitive Science:
A Bibliometric Analysis of Interdisciplinarity

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To the Memory of My Parents,

Moonhee Hong and Gahngwoo Shin

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This study attempts to understand the interdisciplinary dimensions of cognitive science by analyzing the overall research interactions among the contributing disciplines to cognitive science through citation analysis of its literature. Three approaches to achieve this purpose are used. First, citation patterns of six constituent disciplines represented in the journal *Cognitive Science* (anthropology, linguistics, philosophy, psychology, computer science, and neuroscience) are analyzed for the time period of 1977-1996. Second, based on a journal inter-citation network, research interactivity among the above disciplines is analyzed along with measures of relative journal importance. Third, clusters of journals based on co-citation similarity are formed and mapped to illustrate the structure of cognitive science literature.

The analysis reveals that psychology, computer science, and linguistics were the key contributory and reference disciplines in *Cognitive Science* from 1977 to 1996. While the initial dominance of computer science gave way to psychology, computer science always remained prominent. Anthropology, philosophy, and neuroscience remained marginal. Authors from the dominant disciplines of

psychology and computer science have tended to look inwards, drawing heavily on their own respective disciplines; conversely, authors from the less dominant disciplines tended to look outside their home areas in their research.

The analysis of research interactivity in the journal citation network generally corroborated the above findings. Network analysis further revealed that the constituent disciplines progressed from internal modes of research interactivity to multidisciplinary research interactivity over time, and bonded together to form a stabilized platform of cognitive science. The latter made possible the designation and analysis of a key set of cognitive science journals. Co-citation patterns in general produced findings similar to the inter-citation patterns of journals.

The broad picture that emerges indicates that cognitive science has formed into a relatively mature, open, stable, diffuse, and dynamic system of interactive disciplines. But two dominant orientations or schools (one centered on the mind and brain, and the other on computational intelligence) continue to exist as side-by-side competitors and collaborators.

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CHAPTER I. INTRODUCTION

1.1. BACKGROUND

The emergence of a new scientific research area can largely be seen as splitting or merging parts of existing disciplines (Machlup and Mansfield, 1983). In particular, the emergence of an interdisciplinary area is viewed as a merger or fusion of component contributions from several disciplines to solve a common research problem. The term "discipline" in general is used to characterize a recognized branch or segment of knowledge. The breaking up of knowledge into separate segments or units implies a dominant pattern of knowledge growth and is based on a variety of different criteria, depending on levels of specificity and different types of analyses (Bechtel, 1986). Thus, a particular approach to breaking up knowledge forms the core of Western science (Jantsch, 1980). Intellectually, a discipline represents historical, evolutionary aggregates with shared research interests in the sense that the nature of a discipline may change and evolve over time depending on intellectual and social influences (Chubin, Porter, and Rossini, 1986).

Efforts to establish separate and identifiable disciplines were being made in the nineteenth century by classifying disciplines in terms of their specific subject matter and their distinctive corpus of knowledge and techniques that contributed to the advancement of knowledge (Briggs, 1977; Mulkay, 1977; Klein, 1990). In the early decades of the twentieth century, some critics of the increasing specialization of disciplines believed that the advancement of knowledge would grow out of an increasing synthesis of subject matter rather than the future proliferation of individual disciplines. Meanwhile, during the 1950s and 1960s, the term "interdisciplinary" began to be used to denote the interaction between two or more disciplines, for the purpose of integrating or coordinating concepts, theories, methods, and research results. Klein (1990: 22-23) states that the modern concept of interdisciplinarity has evolved in the following four ways:

1. by attempting to retain and, in many cases, reinstill historical ideas of unity and synthesis;
2. by the emergence of organized programs in research and education;
3. by the broadening of traditional disciplines;
4. by the emergence of identifiable interdisciplinary movements.

In studying scientific development, the nature and structure of a discipline can be revealed by investigating not only the internal development of scientific knowledge (i.e. its corpus of centeral ideas) in a given field of inquiry, but also the social processes associated with the scholarly activities rather than the contents of science (Lemaine, Macleod, Mulkay, and Weingart, 1976). Whereas the former is a philosophical, epistemological approach to science in the realm of knowledge, in terms of concepts, theories, laws, problems, methods, etc., the latter is a social, institutional approach to science in the realm of activities, in terms of institutions, scientists, publications, meetings, communication transactions, etc. While the philosophy and history of science tends to be more concerned with the former, the sociology and social history of science tends to be concerned with the latter. There are no sharp boundaries, however, between the two approaches to knowledge (Bechtel, 1988). They may be related in some respects and not necessarily incompatible, although measuring such relations is difficult. The present study will basically employ the latter approach to investigating research interactions between or among disciplines in a sociological realm associated with written communication patterns.

More than four decades ago, a series of research efforts conducted by people in different disciplines developed a new approach to understanding the human mind in the context of the information movement. Simon (1981) takes the year of 1956 as the birth of cognitive science. He lists the following contributions as milestones in the cognitive science movement (sources are listed in the bibliography):

- George Miller's theory of the limited capacity of short-term memory
- Noam Chomsky's analysis of the formal properties of transformational grammar
- Jerome Bruner, Jacqueline Goodnow and George Austin's portrayal of strategies as mediating constructs in cognitive theory (in their book *A Study of Thinking*)
- Allen Newell and Herbert Simon's publication of the *Logic Theorist*, which describes computer programs that solve problems through imitation of humans by heuristic search.

Since then, the information processing approach of the human mind grew as a fundamental focus of inquiry, and cognitive science emerged as a new interdisciplinary area with a common set of research agendas about cognition vis-à-vis computation.

Cognitive science has grown from its rudimentary origins in psychology, artificial intelligence, linguistics, philosophy, neuroscience, and anthropology has undergone substantial transformation. The scope of cognitive science now embraces a number of other disciplines and has hybridized into such areas as cognitive neuroscience, cognitively oriented biotechnology, and so on. Few attempts, however, have been made to actually assess the scope and domain of cognitive science and its transformations over an extended time period.

The purpose of this proposed study is to conduct a systematic review of research interactivity in cognitive science in terms of its written communication patterns and, thereby, to establish the scope and domain of the interdisciplinary area at different points in time from its inception to the present.

1.2. PROBLEM

Cognitive science as an interdisciplinary area may be seen to exist as a coherent but dynamic intellectual entity, provided that a construction of its bridges to neighboring areas of study can be discerned. To discern the connections to different areas of study, the interactions between or among the different research areas can be investigated. Such an investigation should reveal the field's state of scientific progress and relative maturity.

A key problem that arises in such a study is how operationally to evaluate and measure the scientific growth and communication interactivity of research efforts among contributing fields. Such evaluations and measurements are necessary if one is to delineate the interdisciplinary dimensions of the broader domain of cognitive science. Since the scope and domain of cognitive science have not yet been well-defined, despite its impressive record of scientific advances, the problems of identifying scientific journals under the cognitive science category and of designating the field's *core* scientific journals have yet to be resolved.

1.3. OBJECTVIES

The main purpose of this study is to analyze the overall research interactions among the contributing disciplines of cognitive science[1] through the citation analysis of its literature in order to understand its interdisciplinary dimensions. The secondary purpose is to investigate the extent to which the related disciplines

[1] In this project, the phrase "cognitive science" refers to the field of cognitive science, whereas the tile "*Cognitive Science*" is used to refer the journal *Cognitive Science*.

contribute to cognitive science through an exchange of communication. Such communication patterns are well summarized in the interdisciplinary journal *Cognitive Science*, which initiated publication in 1977. This investigation will analyze the communication patterns from 1977 through 1996. This will be done through citation analysis of *Cognitive Science* and its citation links to other leading journals, since these are collectively the primary means of formally recording the chief contributions of the interdisciplinary area. The third objective is to identify a number of core journals that may be categorized as cognitive science journals by mapping the overall journal literature by its inter-citations. The fourth objective is to cluster the journals based on co-citation similarity patterns in the citing literature and to generate a two-dimensional map that represents graphically the structure of cognitive science literature.

The main thrust of the research, then, is to present a broad, macro-level analysis using citation patterns in the journal literature. Through an analysis of research interactions, this research will also depict patterns of convergence of the component disciplines into cognitive science over selected time periods.

1.4. KEY TERMINOLOGY

This section elucidates some key concepts and terms that are to be employed in this investigation. Specifically, the areas of study such as cognitive science, artificial intelligence, psychology, linguistics, philosophy, anthropology, and neuroscience are preliminarily defined and discussed. These definitions are derived primarily from the literature of cognitive science, rather than from more general sources, in order to achieve a higher degree of semantic consistency and agreement in this investigation. Likewise, the rather nebulous terms of "field," "subfield," "discipline," and "interdisciplinary area" are defined and briefly discussed. These terms are defined in a preliminary fashion, inasmuch as this investigation is expected to shed new light on their meaning and perhaps provide more rigorous definitions.

1.4.1. DEFINITIONS OF COGNITIVE SCIENCE AND ITS COMPONENT DISCIPLINES

Cognitive Science has been defined in the following representative ways during its short history:

> Cognitive science is the study of the principles by which intelligent entities interact with their environments. By its very nature, this study transcends disciplinary boundaries to include research by scholars working in such disciplines as neuroscience, computer science, psychology, philosophy, linguistics, and anthropology (Sloan Foundation, 1978, 75)

> Cognitive Science is a new discipline, created from a merger of interests among those pursuing the study of cognition from different points of view. The critical aspect of Cognitive Science is the search for understanding of cognition, be it real or abstract, human or machine. The goal is to understand the principles of intelligent, cognitive behavior (Norman, 1981, 1).

> Cognitive science is the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation (Simon and Kaplan, 1989, 1).

> I define cognitive science as a contemporary, empirically based effort to answer long-standing epistemological questions—particularly those concerned with the nature of knowledge, its components, its source, its development, and its employment. Though the term *cognitive science* is sometimes extended to include all forms of knowledge—animate as well inanimate, human as well

as nonhuman—I apply the term chiefly to efforts to explain human knowledge (Gardner, 1985, 6).

Researchers in psychology, linguistics, computer science, philosophy, and neuroscience realized that they were asking many of the same questions about the nature of the human mind and that they had developed complementary and potentially synergistic methods of investigation. The word *cognitive* refers to perceiving and knowing. Thus, cognitive science is the science of mind. Cognitive scientists seek to understand perceiving, thinking, remembering, language, learning, and other mental phenomena (Stillings et al., 1995, 1).

In order to provide an optimal degree of breadth of meaning and sufficient operational rigor, cognitive science is defined in this study as an interdisciplinary area that seeks to understand the nature of the human mind by means of approaches to its incorporating aspects of relevant phenomena found in such diverse disciplines such as psychology, artificial intelligence, linguistics, philosophy, neuroscience, and anthropology. Descriptions and something of the general contributions of each of these disciplines to the interdisciplinary area of study are as follows.

Psychology is a scientific discipline that studies general mental processes and behavior in living organisms. In particular, cognitive psychology concerns human cognition, our capacities for sensory perception, memory, thinking, problem solving, and learning. The cognitive psychologists who are oriented towards cognitive science view the human mind as an information processing system which is very powerful in some circumstances and yet very limited in others. Cognitive psychology contributes to cognitive science in that it tries to develop theories of highly general cognitive capacities by asking what kinds of general information processing capacities a mind must have in order to do the many things it does (Stillings et al., 1995).

Artificial intelligence (AI) is the science of making artificial computer systems that are able to do things that would require intelligence if done by humans. AI researchers have been using knowledge about human intelligence acquired from other disciplines, especially cognitive psychology, in order to develop and test computer programs that exhibit characteristics of human intelligence. There has been a close relationship between AI and cognitive psychology, and their mutual synergy was a major motivation for creating a common ground in cognitive science (Simon and Kaplan, 1989).

Linguistics is concerned with the structure of human language and the nature of language acquisition. Its contribution to cognitive science consists of seeking to understand how linguistic knowledge is represented in the mind, how it is acquired, how it is perceived and used, and how it relates to other components of cognition (Stillings et al., 1995).

Philosophy is a foundational discipline in that it makes the construction of other disciplines possible, and it also pays constant attention to the foundations of those disciplines as they are practiced. In their search for more rigorous methods of reasoning, philosophers have contributed to cognitive science the powerful tool of modern symbolic logic. Much recent work in the philosophy of mind, the philosophy of language, and epistemology has been related to cognitive science (Stillings et al., 1995).

Neuroscience includes the study of physical processes and structures in the nervous system. The contribution of neuroscience to cognitive science includes attempts to explain how neurological systems yield complex information processing—understanding from mind to brain, from thought to neuron, etc. It is the crea that has provided a connectionist approach to the computational architecture of the human mind (Stillings et al., 1995). The basic assumption here is that knowledge about fundamental principles of structure and process in the nervous system shouid be able to contribute to the initial construction of a theory of cognitive architecture. Ideally, a theory of cognitive architecture could be the joint product of findings at both computational and biological levels of analysis.

Anthropology in the cognitive science context—also called cognitive anthropology or ethnosemantics—contributes to cognitive science in that researchers undertake systematic collection of data concerning the naming, classifying, and concept-forming abilities of people living in remote cultures, and then seek to describe in formal terms the nature of these linguistic and cognitive practices (Stillings et al., 1995).

1.4.2. OTHER TERMINOLOGY

In the second edition of the Oxford English Dictionary, field is defined as follows: an area or sphere of action, operation, or investigation; a (wider or narrower) range of opportunities, or of object, for labour, study, or contemplation; a department of subject of activity or speculation. In this study, the term "field" will be used to mean an area of study, and at times, will be used interchangeably with "discipline". A subfield in this study will be used to mean a specialized area of study within a field or a discipline.

A discipline is defined in the Oxford English Dictionary as follows: a branch of instruction or education; a department of learning or knowledge; a science or art in its educational aspect. The term "discipline" in this study will be used to mean a recognized branch of knowledge within the domain of learning. An interdisciplinary area is defined as an area of study pertaining to two or more disciplines or branches of learning. It implies the interaction between two or more disciplines, related or unrelated, through teaching or research programs, for the purpose of integrating or coordinating concepts, methods, and conclusions (Briggs, 1977).

1.5. THE NATURE OF COGNITIVE SCIENCE

This section introduces some background knowledge of cognitive science in terms of its interdisciplinarity and its interaction among its contributory disciplines.

1.5.1. THE INTERDISCIPLINARY NATURE OF COGNITIVE SCIENCE

The question of the interdisciplinarity of cognitive science is raised whenever scientists try to define its nature and scope. Cognitive science has been defined recently by Baumgartner and Payr (1995:12) as "a joint effort of specific disciplines to answer long-standing questions about the working of the mind—particularly knowledge, its acquisition, storage, and use in intelligent activity." The component disciplines are said to consist largely of psychology, artificial intelligence, linguistics, philosophy, neuroscience, and anthropology. Thus, cognitive science can be characterized inherently as an interdisciplinary activity. However, the boundaries of the interactions with the contributing disciplines are far from being well-defined (Pylyshyn, 1991). The essence of cognitive science is rather holistic in that cognition may be viewed as an integral component of a larger natural context: organisms, persons, groups, society, and culture. In this broad context, a full understanding of cognition in biological or artificial systems requires a search for the principles of intelligent behavior from different points of view (Norman, 1981).

Two major schools of cognitive science have evolved (Rapaport, 1990). One is composed of researchers who study the mind, brain, and cognitive behavior of organisms holistically. The other is composed of scientists who believe that mental states and processes are primarily computational in nature and can be simulated as intelligent systems that are not human in order to abstract the requisites of intelligence or the human mind. In turn, both of these schools distinguish between cognitive computations that use either "serial-symbolic" processing or "parallel-connectionist" processing. While the symbolic processing approach has been predominant in cognitive science, the connectionist approach has been relatively successful in integrating the findings of investigations on the workings of neural systems.

During the last decade, many books have been published and conferences held on cognitive science. As Ezquerro and Larrazabal (1992) point out, there are no genuine criteria for classifying publications as contributing to cognitive science. This might be the reason that cognitive science is a relatively young area of study which is seeking its own identity, still involved in a process of formation and consolidation within the scientific community. It is apparent, however, that both cognition and intelligence are extremely complex phenomena, the investigation of which requires the full exploitation of a wide range of disciplinary approaches. Up to the present, the basic idea behind the interdisciplinarity of cognitive science is that each discipline employs its own particular methods in order to construct common models and theories of cognitive functions and their interrelationships. These common models and theories are developed to address the nature of intelligent, cognitive behavior from different perspectives. Then the question is raised: Will the interdisciplinary area of cognitive studies from the different perspectives remain as separate disciplinary research clusters or will new separate disciplines emerge, calling for the unity between forms of knowledge and their respective disciplines? (Stillings et al., 1995; Bechtel, 1988).

Despite the question being raised, efforts have been made for a convergence of elements of disciplines into a coherent area of study: cognitive science. With the continuing effort in strengthening cognitive science programs in the U.S. (National Science Foundation, 1991) and Europe (Orban, Singer, and Olebernsen, 1991), the establishment of institutions and studies for cognitive science as a separate area of study now signals the emergence of a second generation of cognitive science researchers (Gardner, 1985; Baumgartner and Payr, 1995). The Cognitive Science Society, which was founded in 1977, has held research meetings each year since 1979 and has designed and produced its own conference which has focused on cognitive science courses in the new subject to universities. A full-fledged discipline of cognitive science appears to be developing, evidenced by the establishment of new academic departments and programs and the publication of several textbooks (Gardner,1985; Johnson-Laird, 1988; Posner, ed., 1989; Luger, 1994; Stillings et al., 1995). These efforts, in the meantime, may still be characterized as "interdisciplinary research clusters" which allow for research collaboration and interdisciplinary communication (Bechtel, 1986).

1.5.2. RESEARCH INTERACTIONS IN COGNITIVE SCIENCE

As mentioned in the previous section, the complexities of the nature of human cognition and intelligence naturally require the domain of inquiry to be of an interdisciplinary nature. The different perspectives need to come collectively to a scientific understanding that addresses the nature of intelligent behavior. Ultimately, the constitutent disciplinary areas tend to develop their own unique perspectives and methodologies that eventually contribute to the advancement of cognitive science. The intellectual boundaries may interact through informal or formal communications in the form of concepts, theories, data, methods, problems, and perspectives, as they are developed and transformed across the disciplines (Newell, 1983). Such interactions of the content of scientific domain knowledge may occur through scholarly activities such as publications and conference meetings.

To investigate the status and extent of research interaction in terms of communication activities rather than content of scientific ideas, objective and unobtrusive methods have been used. Among them, bibliometrics, a quantitative study of literatures as they are reflected in bibliographies (White and McCain, 1989), is used as a leading method to study written communication patterns. In particular, citation analysis has been successfully used to provide a macro-analysis of communication patterns or research interactions by summarizing the cross-citations between different disciplines and problem areas (Pylyshyn, 1983).

CHAPTER II. LITERATURE REVIEW

The application of bibliometrics to cognitive science appears to be at a rudimentary stage of development. The few studies that have been made appear not to be very systematic or rigorous, nor do they address questions that relate to the broader scope and interdisciplinary context of cognitive science. These shortcomings exist partly because the area of study is very young. Accordingly, this brief literature review will discuss citation analysis in general, the general dimensions of the bibliometric studies in cognitive science and interdisciplinary areas of study. Finally, an input-output approach to the measures of journal inter-citation will be reviewed.

2.1. CITATION ANALYSIS

The basic purpose of science is to produce of new fundamental knowledge; the eventual utility of this knowledge, however, is often uncertain. Furthermore, as science progresses, some kind of evaluation parameters are needed to measure the quality of science, which can be used to encourage the creativity of researchers and assess the magnitude of the knowledge produced. In terms of the sociology of science, while the quality of individual works or journals may not be easy to measure, citations to other works might seem to hold some potential as at least a partial indicator of scientific quality (Price, 1965; Cole and Cole, 1973; Garfield, 1979) or a measure of an author's or a group's contributions to the growth of knowledge in a particular subject area (Cronin, 1984). Since citations are the formal, explicit linkage between publications that have some point in common, they tend to imply that in the author's mind there is a relationship between a part or the whole of the cited work and that of the citing work (Egghe and Rousseau, 1990).

Citation analysis is a bibliometric method that uses reference citations found in scientific papers as the primary analytical tool. Citation data are used for different kinds of analysis using different methods. Generally, these methods can be divided into three categories. The first category is to use simple counts of citations to a document or a set of documents over a period of time from citing documents. Citation counts are used to investigate the performance of scientists, nations, and journals, resulting in rank orderings of the designated unit of analysis for evaluative purposes. This application of citation analysis to derive indicators of academic productivity influences the decisions of administrators in such things as grant awards, tenure evaluations, and organizational hiring. These uses of citation data call for an understanding of its limitations and the problems inherent in citation analysis (Garfield, 1979).

The second category is to study the cited and citing relations in networks at many levels: authors, references, citations, institutes, or journals. Among those levels, journals as the unit of analysis were often used in bibliometric research, possibly for the following reasons: 1) the journal is as a major communication channel; 2) the large proportion of the budget in research libraries is allocated for journals and other periodicals; and 3) the availability of the annual statistical publication, *Journal Citation Reports (JCR),* by the Institute of Scientific Information (ISI) (White and McCain, 1987). The *JCR* presents cumulated publication and citation statistics at the level of the citing and cited journals. Based on inter-citation patterns, information flows in terms of making references and receiving citations can be analyzed. The details of journal inter-citation network are discussed in the section 2.4.

The third category is to analyze the different relationships between cited documents reflecting publication linkages: bibliographic coupling and co-citation analysis (Egghe and Rousseau, 1990). A single item of reference shared by two documents is defined as a unit of coupling between the documents. The coupling strength between documents is measured as the number of coupling units, or citations, the two documents share. This bibliographic coupling produces an association between source documents that is static, referring backwards in time to documents already published. Co-citation is a measure of the frequency with which two publications are cited together in a third publication. The number of source documents that cite a pair of reference documents becomes the measure of association between the cited pairs. To have a strong measure of co-citation, the two documents must be cited as a pair over a large number of source documents. The distribution of their frequencies is dynamic in the sense that by adding new publications to the data set, the frequencies and the distributions are changed. For the purpose of mapping the structure of science, co-citation analysis has been popular in bibliometrics and has successfully been applied to individual works, authors, and journals. In a co-citation map, two points that denote documents are joined when the co-citation strength of the associated pair of documents is above some threshold value set by the researcher. The use of a co-citation threshold yields a disconnected graph in which documents are distributed among the components. These components create subject specialty areas in certain investigations (McCain, 1986, 1991; White and McCain, 1989).

There is a large body of evidence supporting the notion that citation data are associated with various subjective and objective performance measures including journal evaluation, publication productivity, and communication patterns, demonstrating a strong relationship between those measures (McAllister, Anderson, and Narin, 1980; Gordon, 1982; Borgman, 1990; Liu, 1993). While this evidence validates using unobtrusive and objective citation data as evaluation purposes, some challenges have been made to the assumptions and methods of many studies in the literature. There are underlying assumptions in the use of citation data: citation of a document implies use of that document by the citing author; citation of a document reflects the merit (quality, significance, impact) of that document; citations are made to the best possible works; a cited document is related in content to the citing document; all citations are treated equally (Smith, 1981). In the last assumption, some measures have been proposed and carried out to use different weights for each citation, which will be explained more fully in the methodology section.

In the foregoing type of citation analysis, however, the underlying reasons or motivations that an author cites other works are not necessarily taken into account. Citation can be either negative or positive, as citations to relevant work used in a publication or as criticisms of work that may not be central to the publication. The complexity of determining what citation means and the variety of motivations for citing other works calls for additional behavioral study of citers' motivations (Brooks, 1986). Garfield (1977: 85) cautioned against unqualified use of citation data because inferences can lead to spurious or specious conclusions. But he did provide a list of the reasons that authors cite other works which, if well founded, can serve various analytical purposes with a reasonable degree of validity:

- paying homage to pioneers;
- giving credit for related work (homage to peers);
- identifying methodology, equipment, etc.;
- providing background reading;
- correcting one's own work;
- correcting the work of others;
- criticizing previous work;
- substantiating claims;
- alerting readers to forthcoming work;
- providing leads to poorly disseminated, poorly indexed, or uncited work;
- authenticating data and classes of fact—physical constants, etc.;
- identifying original publications in which an idea or concept was discussed;
- identifying original publications or other work describing an eponymous concept or term;
- disclaiming the work or ideas of others (negative claims);

- disputing priority claims of others (negative homage).

Problems inherent in citation analysis also can stem from multiple authorship, type of sources, field variations, biased citing, self-citing, formal or informal influences not cited, and possible technical errors involved (Smith, 1981; Brooks, 1986; MacRoberts and MacRoberts, 1989; Egghe and Rousseau, 1990; Liu, 1993). Because data are retrieved from existing indexing and abstracting services, the selection of journals and articles being included in indexing and abstracting processes are crucial in the use of citation data and are dependent on their filtering processes (Rice et al., 1989). Possible sources of measurement error using *Social Science Citation Index (SSCI) Journal Citation Reports (JCR)* include discrepancies between citing and cited data, changed or deleted journal titles, and deviating abbreviations. A 25 percent measurement error was found in data collected from 76 journals in library and information science and communication science from *SSCI JCR* because of such measurement errors (Rice et al., 1989).

2.2. CITATION ANALYSIS IN COGNITIVE SCIENCE

Pylyshyn (1983) conducted a survey to determine the extent of cross-disciplinary citation between the literature of artificial intelligence (AI) and those of cognitive psychology and cognitive science, respectively. For artificial intelligence (AI), Pylyshyn used the *1977 International Conference Proceedings on Artificial Intelligence* and two years of the journal *Artificial Intelligence* to obtain a random sample of 528 references cited. The majority of citations referenced AI papers, while citations of psychological and linguistic papers were surprisingly rare. He surmised that since much of AI research is essentially concerned with developing computational techniques for information processing, much of the work in psychological literature may be irrelevant to the AI community. The AI community tended at the time and still continues to be interested in creating and replicating intelligence computationally rather than understanding the mind or the nature of intelligence.

In the area of cognitive psychology, Pylyshyn included 1,200 references from a sample of two years of the journals *Cognitive Psychology, Cognition, and Memory* and *Cognition*. The majority of these articles cited psychological works and journals in conventional experimental psychology rather than works categorized as cognitive psychology. Articles in linguistics, artificial intelligence, and philosophy were also cited. Ironically, it appeared that cognitive psychology was more closely related to general experimental psychology than to any other subfield of cognitive science. The existence of interdisciplinarity was hardly revealed statistically in this simple survey. Pylyshyn nevertheless detected signs of the development of a major, new cross-disciplinary area of study.

To present a better picture of interdisciplinarity, Pylyshyn surveyed citations of two years of the journal *Cognitive Science*. Out of 331 citations, psychology, artificial intelligence, philosophy and logic, linguistics, and neurophysiology were cited. Despite the variety of disciplinary citations, the extent of cross-citation did not demonstrate statistically the existence of substantial cross-fertilization.

In a study of the interdisciplinary context in artificial intelligence (AI), Khawam (1992) investigated the citation patterns in three AI contributing fields (humanities, social sciences, and the sciences) to determine each field's research base. Journal articles were used as the main unit of analysis and were retrieved, based on AI key terms, from each corresponding field's citation index, *Arts and Humanities Citation Index*, *Social Sciences Citation Index*, and *Science Citation Index*.

The fields of the source journals in which citations of the journal articles were published were identified according to the journal listings under each index and the Dewey classification numbers of the journals, if not listed in the index, were used to define the fields of the journals. The variables, field cross-citation rate, field cross-citation diversity, journal citation rate, proceedings citation rate, and age of cited literature, were compared among the AI-related journal literature of the three fields: humanities, social sciences, and sciences. It was found that the sciences had a greater role than both the humanities and social sciences in contributing to the AI research base. Thus, the hypothesized interdisciplinary nature of AI research was not confirmed. The research concluded that these AI research bases were fragmented, with each field working on its own AI paradigm(s).

To assess interdisciplinarity of neural networks research, McCain and Whitney (1994) focused on the degree of subject dispersal across sets of journals representing neural networks research (NNR) published between 1988 and mid-1991. Since neural networks is a rapidly developing area that encompasses certain portions of the natural, social, and applied sciences, they defined the NNR literature in three different ways: 1) citation analysis of five NNR journal titles; 2) publishing patterns based on journal articles retrieved from a database by NNR keyword identification and NNR research front specialty (RFS) retrieval. The RFS consists of a given year's published research output in the topic area represented by the co-cited document cluster, which indexed in SCISEARCH of the ISI as an additional subject retrieval tool. Subject dispersions of highly cited journals and those frequently publishing topic-relevant articles were compared with data from a recent survey of neural networks researchers. Publication subject patterns paralleled the survey results, concentrating heavily in the physical sciences and engineering, while the biological and psychological literature is more visible in the citation patterns. The study demonstrated the value of multiple approaches in bibliometric analysis of interdisciplinary research in emerging areas of study with more elaborate representation of formal communications patterns, as well as identification of information sources necessary to support scholarly research through the examination of both publication and citation patterns.

To analyze the development patterns of artificial intelligence in terms of stability and coherency of selected journals, van den Besselaar and Leydesdorff (1996) used factor analytic methods for the time period of 1982-1992. Using mapping structure of citing journals in the journal *Artificial Intelligence*, they concluded that the structure of the field artificial intelligence became more stable after 1988, showing the clear delineation of the AI-cluster. The specialty areas that were visible in the environment of AI were pattern analysis, computer science, and cognitive psychology. Robotics research also appeared in the environment of AI in the 1990s. Expert systems research was a part of the core of AI communication patterns, while neural networks research emerged as a separate specialty rather than in the environment of AI .

2.3. CITATION ANALYSIS OF INTERDISCIPLINARY AREAS

The exchange of research between disciplines or their subfields can be analyzed via the frequencies of citing and cited articles. Data from citing and cited journals, arranged in matrix form, can represent information flows among the groups consisting of journals in different fields. Hence, analysis of information flows may be conducted by showing the changing, internal structures of the fields. In particular, the influence of the contributory or cited fields on the recipient or citing fields can be measured.

In an example of interdisciplinary citation analysis in social sciences, Neeley (1981) demonstrated that management journal literature is more interdisciplinary than any of the other social sciences studied—economics, psychology, sociology, and political science. He found that about 25 percent of the citations found in the management literature were to economics, psychology, or sociology journals. Management was especially dependent on psychology, but the relationship was strictly unilateral. Rigney and Barnes (1980) employed a 5% sample of citations from the five core journals of five disciplines (sociology, anthropology, economics, political science, and psychology) from 1936 to 1975, to study interdisciplinary relationships. Their research showed an imbalance of integration in the social sciences. The study found that while sociology, anthropology, and political science are fairly receptive to literatures of other social science disciplines, psychology and economics remained relatively self-contained. Cheung (1990) analyzed the citations of 11 social work journals published from 1981 to 1985 to examine the interdisciplinary relationship between social work and other disciplines. Out of 22 social work journals listed in *Social Science Citation Index*, 11 journals were selected which were above the mean impact factor of social science journals. Citation data were grouped by disciplines instead of by specific journals to study the relationships among disciplines. The study revealed that social work had a weak relationship of information exchange with women's studies and ethnic studies in spite of frequent discussions of those areas in social work, and showed a lack of focus on some practice areas such as alcoholism, drug addiction treatment, and criminal habitations, and a relatively weak contribution to public policy. In general, while social work has based its knowledge on other disciplines such as social work in practice, family studies, psychology, developmental psychology, medical science, and social issues, the interdisciplinary approach of social work aids knowledge expansion of the information exchange process with other disciplines such as education, family studies, clinical psychology, psychiatry, sociology, social issues, geriatrics and gerontology, law, psychology, and public administration.

Although the cross-citations among the four science-based grand categories used by the U.S. National Research Council (engineering, life sciences, physical science, and social sciences) have not been very revealing, Porter and Chubin's

(1985) cross-disciplinary research demonstrated a potential indicator of interdisciplinarity, an estimated rate of citation outside category (COC), using the JCR data base within subcategories (demography, operations research and management science, toxicology) of those grand categories. COC was calculated as the ratio of outside category citations to total citations excluding all other citations cited five or fewer times by the journal in question. Toxicology, which is a more application-oriented area, was found to be more cross-disciplinary than the other two subcategories.

Hurd (1992) used the faculty members' publications of the chemistry department in the University of Illinois at Chicago to determine the extent of interdisciplinary research, to evaluate the range of sources supporting these chemists' research, and to suggest implications for library organization and services that would follow from these findings. Using 57 articles published by the chemists in 26 journals, she calculated citations outside category (COC) as a measure of the interdisciplinarity of the chemists' research, which was adopted from Porter and Chubin's (1985) study. The study showed a high degree of interdisciplinary use of journals, with the average COC of 49 percent for the 57 papers. The chemists cited not only the journals identified with their own disciplines but also other titles identified with biology, physics, and a number of other scientific fields.

As for questions of convergence of two related fields, Borgman and Rice (1992) studied the linkage between the disciplines of information science and communication science and their linkage trends over the eleven-year time period of 1977–1989. Their analysis of 77 journals revealed less evidence of the convergence between the two fields than expected.

In biotechnology, McCain (1995) identified significant journals that existed outside of the core journals by using citation and subject analyses. The *Journal Citation Reports (JCR)*, *SCISEARCH,* and *Biotechnology Abstracts* were used as filters to extract the journals and to cluster and map them according to their co-citation and subject heading profiles. Her research indicated that as the field settles into an established research area, particularly in an application-oriented area, peripheral journals, nevertheless, may be identified as significantly related, suggesting that the exclusive use of core sets of journals might be inadequate for many research analyses.

To investigate the relationship between research collaboration and interdisciplinarity, Qin, Lancaster, and Allen (1997) used 846 journal articles extracted from the *Science Citation Index* database for 1992. To measure interdisciplinarity, the number of disciplines represented in the journals cited were based on collaboration, in terms of the number of authors, number of instituational affiliations, number of affiliation disciplines, and type of collaboration. They found the levels and types of interdisciplinary collaboration varied in different disciplines, but the disciplines generally tended to be highly interdisciplinary, especially in biology and medicine. They also conducted a questionnaire survey to support and supplement the results of bibliometric data, in respect of forms of collaboration, channels of information, and use of information. In addition to bibliometric analysis, the survey identified some factors affecting collaboration, such as type of institution, nature of research problems, personal contact with collaborators, and funding. The study confirmed that supplementing with bibliometric analysis, survey techniques can add the value of qualitative analysis to the quantitative analysis of interdisciplinary studies.

2.4. JOURNAL INTERCITATION ANALYSIS

In the scientific community, a published work in a journal uses related and previously published works as inputs. Such referencing processes involve recognizing the context of the prior research and the provision of acknowledgments. One way to view the relationships involved is through the analogy of the marketplace where the one who cites the works of others plays the role of a "buyer," and the one who is cited by others plays the role of a "seller" (Rescher, 1989; Goldman, 1991). The transactions between the two sets of works consist then of *citing* and *being cited.* In this sense, citation data can be used to measure a flow of knowledge or information and can draw a relationship over the set of journals used in a subject area or among different subject areas. This interactive function implies a circular flow of information in the sense that all the works in the analyzed set are citing other works, and are eventually cited by others through time.

The information flow concept utilizes input-output analysis, which is a branch of economic statistics that is used for general theory of production, based on the economic interdependence of producing industries in the economy. The input-output analysis was developed by Wassily Leontif in the 1930s (Miller and Blair, 1985), which brought him the Nobel Prize in Economic Science in 1973. A fundamental underlying relationship of input-output analysis is that one sector's production is determined by the consumption of other sectors of economy. The dependency nature of the input-output model has been applied to social systems, including the analysis of social interactions and social structures (Studer, Barboni, and Numan, 1984).

Input-output analysis can also be viewed in the social networks context, in which journals serve as actors and their citation behaviors as actions and these are interdependent components. Relational linkages between journals by those *citing* and those *being cited* are channels for information flow. Patterns of relations among journal can thus be viewed as structural properties of literature. The duality of *citing* and *being cited* is stressed by the fact that citing entails an input to a system while being cited may entail an output to a system. In citation behavior, it can be seen also as a social behavior exchanging intellectual property. The dual nature of reference-citing behavior creates two systems for analysis in terms of an input-output model. It is known that within each of these systems imbalances can occur, i.e., A does not have to cite B as many times as B cites A. This asymmetry suggests that the systematic contributions of individuals or groups need not be equal. The systematic properties may distribute individuals or groups quite differently within the two phenomena, i.e., *citing* and *being cited.*

In the context of sociology of science, input-output analysis may be simplified in order to apply to a network of different disciplines, different journals, or individual authors (Kochen, 1978). The input-output model has been modified to apply to a network of journals whose data set is arranged in a matrix of journal-to-journal citations (Kim, 1992). The matrix defines a network of journals whose cells contain citation exchanges that represent information flow between the networked journals. In this model, the references made by citing journals are considered to be journal output. In turn, this output may be considered to be a form of input to the cited journals, and hence a form of influence. A citation matrix C consists of the following elements, where J=Journals and $C_{n.m}$=citation counts between J_n and J_m:

$$\begin{array}{llllllll}
 & \underline{\text{Cited Journals}} & & J_1 & J_2 & J_3 & & \dots J_m \\
\underline{\text{Citing Journals}} & J_1 & & C_{1.1} & C_{1.2} & C_{1.3} & & \dots C_{1.m} \\
 & J_2 & & C_{2.1} & C_{2.2} & C_{2.3} & & \dots C_{2.m} \\
 & J_3 & C= & C_{3.1} & C_{3.2} & C_{3.3} & & \dots C_{3.m} \\
 & \cdot & & \cdot & \cdot & \cdot & & \dots \cdot \\
 & J_n & & C_{n.1} & C_{n.2} & C_{n.3} & & \dots C_{n.m}
\end{array}$$

This matrix is asymmetric with relatively high values in the diagonal where self-citations are counted. This model produces an input-output ratio for each journal that reflects the status of the journal in a given network. It represents the interactions of a journal within that particular network and indicates the extent to which the set of network journals depends on a given journal.

In bibliometrics, the input-output model has been modified to apply to a network of journals whose data set is arranged in a matrix of journal-to-journal citations (Kim, 1992). The matrix defines a network of journals whose cells contain citation exchanges that represent information flow between the networked journals. In this model, the references made by citing journals are considered to be journal output. In turn, this output may be considered to be a form of input to the cited journals, and hence a form of influence. The model produces an input-output ratio for each journal that reflects the status of the journal in a given network. It represents the interactions of a journal within that particular network and indicates the extent to which the set of network journals depends on a given journal.

One type of useful statistical data provided in the *Journal Citation Reports* (JCR) is the impact factor. The impact factor of a journal in a given year **t** is defined as: the number of citations in year **t** to items published in the journal in years **t**-1 and **t**-2, divided by the number of citable items published in that journal in years **t**-1 and **t**-2 (Todorov & Glanzel, 1988; Nisogner, 1994). For example, the impact factor for a 1995 journal is defined as the number of 1995 citations to 1994 and 1993 items, divided by the number of citable items published in 1994 and 1993. Although that impact factor provides a size-independent ratio by normalizing for the total number of citable documents published in the journal, it suffers from various limitations: it takes only two years citations into account; it depends on only the journals covered by ISI; all the citations are treated equally and not weighted according to their importance; and the citing behavior and relative frequency of citations are specific to disciplinary cultures, practices, and applications (He & Pao, 1986). Therefore, other measures such as the influence measure (Narin, Pinski, and Gee, 1976), the standing measure (Doreian, 1985, 1988), the importance measure (Salancik, 1986) have been proposed and used to resolve the impact factor limitations (Todorov & Glanzel, 1988; Kim, 1992).

Those measures have applied the input-output model in different ways. It differs how to convert the raw citation counts in each cell to adjusted citation coefficients, and what kinds of weighting methods. Based on the adjusted citation coefficients, which are calculated differently for each measure, the input-output model produces differential weighting of citations. The method produces a status score for each journal in the journal network plus an additional component characterized as an exogenous factor. The exogenous factor reflects an intrinsic value that the journal holds which does not depend on the interaction with other journals in the network. In general, the status scores are denoted as follows, where S_i = status score for journal i; w_{ij}=the adjusted coefficient between journal i and j; e_i = exogenous factor for journal i:

$$S_I = w_{i1}s_1 + w_{i2}s_2 + w_{i3}s_3 + \ldots + e_i$$

In matrix algebra terms, this can be succinctly denoted as S = [W]*S + E. These equations serve to make explicit the dependence of information flow on the total outputs of each journal.

The importance measure (Salancik, 1986), denoted by IMP, views the citation coefficient as the extent to which the importance of a journal is depended on by another journal. The importance measure is calculated as the number of citations received by journal A from journal B divided by the total number of references published in journal B. This measure shows the dependency of journal B on journal A. The self-citation in the diagonal in the matrix, $[D]_{ii}$, is set to 0, because the interest is in deriving a general index of structural dependencies determined by others in the network. In matrix algebra terms, this model is denoted as: $IMP_i = [D]_{ij}{*}IMP_i + INT_i$, where $[D]_{ij}$ is a transpose of the coefficients matrix and INT_i is an intrinsic importance that the journal might have independent of its relations with the other journals in the network. To find the unknown IMP_i, Leontif's inversion $[I\text{-}D_{ij}]$ is used, so that the measure becomes $IMP = [I - D_{ij}]^{-1} * INT_i$. The intrinsic value is set to 1, assuming equal merits for all journals in the network. The overall importance of network members can be also partitioned into subgroups to reveal how the members' influence is distributed.

$S_i = [I-D]^{-1}*[D]*[M]*[S]$, where S_i is a decomposition of the structural importance of each network member for each subgroup. The vector M is the matrix representing each journal's membership in a subgroup, and S is the matrix of intrinsic importance attached to each subgroup. This model implies the following: 1) a primary journal's importance to other dependent journals, 2) the relative importance of the dependent journals, and 3) an intrinsic value independent of the contributions to the network.

The influence measure (Narin, Pinski, Gee, 1976) initially defines the coefficient as the number of citations received by journal A from journal B divided by the total number of references journal A given to the other journals in the network. It retains self-citation in the diagonal. It uses an iterative procedure for the calculation of the influence weights.

Let $C=[c_{ij}]$ be the journal citation matrix, where c_{ij} indicates both the number of references journal *i* gives to journal *j* and the number of citations journal *i* receives from journal *k*. The influence weight *w* of i units is:

$$w_i = \sum_{k=1}^{n} \frac{w_k c_{ki}}{s_i} \text{ where } i = 1,\ldots n,\ s_i = \sum_{j=1}^{n} c_{ij}.$$

In a more general form, it is denoted as: $\sum_{k=1}^{n} w_k \frac{c_{ki}}{s_i} - \lambda\, w_i = 0.$

The value of λ (eigenvalue) is sought to be a non-zero solution for the equation. It normalized the weighted average of the weights as 1,

i.e., $\dfrac{\sum_{1}^{n} s_k w_k}{\sum_{1}^{n} s_k} = 1.$

This process is continued until it converges to a stable, consistent set of influence weights.

The measure of standing (Doreian, 1985, 1988) takes the coefficient as the number of citations that journal A received from journal B divided by the sum of the total number of citations journal A received from other journals and the total number of citations made by journal A to other journals in the network. The measure of standing is $S = W*S + e$, where e is an exogenous factor viewed as the standing prior to the period for which the citation data have been obtained. Using Leontif's inversion just as it was used in the importance measure, $S = (I - W)^{-1}$. The initial exogenous factor is set to 1, and this then turns into a journal's prior status in the network; and this status varies across the journal. After t iterations of the measure of standing, $S_{t+1} = (I - W)^{-1} * S_t$ and at convergence it becomes $S = (I - W)^{-1} * S$. It also normalizes the average of the weights as 1.

Basically, these measures differ in the method of taking the coefficient of the network, and in the weighting scheme used. The influence measure only measures the interaction of the journal with the journals in the network, which in turn reflects only the weighted number of citations received from the journals in the network for every reference made to other journals in the network. This measure is very sensitive to changes in the network transactions; it is generally quite different from the rankings from the other two measures, the importance measure and the measure of standing.

CHAPTER III. RESEARCH DESIGN

This study investigates research interactions among the contributing disciplines of cognitive science by examining their citation patterns over time. In light of the problem and objectives described in sections 1.2 and 1.3, this chapter discusses the specific methodological approach employed in this study. The following sections describe the data collection and methodology, and pose the study's major research questions.

3.1. DATA COLLECTION

3.1.1. Citation Patterns of the Journal *Cognitive Science*

This section describes the data collection method utilized to discern the bibliometric patterns. These patterns are reported in Chapter IV.

Data Sources

To investigate general citation patterns in cognitive science, the 1977-1996 issues of the journal *Cognitive Science* were chosen as a sample. To collect references in the articles appearing in the journal *Cognitive Science*, *Social SCISEARCH* (published by the Institute of Scientific Information) was used via the online service DIALOG. For the cited references in *Cognitive Science*, the photocopied reference list in the source articles was used to verify accuracy and completeness of citations. For the sources in which the articles published *in Cognitive Science* are cited, data were extracted from *Social SCISEARCH, Arts & Humanities Search*, and *SCISEARCH.*

Procedures

Cited References in *Cognitive Science*

The cited references in the articles published in *Cognitive Science* for the time periods 1977-1996 were extracted from *Social SCISEARCH* and put into the SAS system for data management. The Library of Congress (LC) classification system was then used to classify the sources of the cited works by subject —That is, into the six constituent disciplines of cognitive science as denoted here. Although this research was initially designed for journal articles only, other forms of literature cited in *Cognitive Science* including books, chapters in collected works, and technical reports were classified in the same way. However, some unpublished reports and manuscripts whose call numbers could not be determined were excluded.[1] First, the LC classification numbers for the cited sources were assigned and those outside of the six constituent disciplines were excluded. A total of 9,453 citations fell into the classification notations that LC used for the six disciplines of cognitive science. Second, the latter were then aggregated into the constituent disciplines of cognitive science and then sub-grouped by year. The citation counts were normalized according to the total number of the citations published per year.

Citing References of *Cognitive Science*

To collect the reference sources in which *Cognitive Science* is cited, the *Social SCISEARCH*, the *Arts & Humanities Search*, and *SCISEARCH* were searched simultaneously. Duplicates from the three sources were removed. Only journals whose cited works include *Cognitive Science* were collected for the time period of 1977-1996. The total number of citing sources of *Cognitive Science* was 6,004 as of December 1997. As in the citing references mentioned previously, the LC class numbers of these cited journals were coded, sorted into different categories, and divided into categories representing disciplinary areas. Citation counts were then aggregated into the constituent disciplines of cognitive science and sorted according to year. The citation counts were normalized against the cumulative total number of articles published each year.

Methods of Classifying the Cited References

Classifying the source journals might at first seem problematic because the particular and fully developed call numbers given to them by LC were generally designed for the purpose of arranging the journals in particular physical locations within a class. The particularity of the numbers is of little consequence to this study, however, because for the most part the only portion of the class numbers that is important here is that which places it in one of the constituent classes of cognitive science. The remainder of the class notation positions an item within such a class, but such positions are of little relevance here. Thus, the Library of Congress classification system has been able to be used for the practical purpose of showing in a general way the discipline to which a work belonged, in terms of a judgment independent of this research.

Anthropology

From the LC class for anthropology which is located in Schedule G, subclasses GN (Anthropology), GR (Folklore), and GT (Manners & Customs –

[1] The total number of excluded documents was 917 or 7.54% of the total citations. This number was deemed statistically insignificant in comparison to the total of 12,155 citations. See Table 3.1 ahead,

General) were used to classify citations for the discipline of anthropology.[2]

Philosophy

For the discipline of philosophy, subclasses in Schedule B, BC, BD, and BH were used to classify the citations. In addition, some citations whose title includes the keyword "philosophy" in Schedule A (General Works), particularly in subclass AZ (History of Scholarship), were classified under philosophy.

Linguistics

Schedule P, in the Library of Congress classification system, particularly subclass P, was used to identify the discipline of linguistics.

Computer Science

Classifying the citations of such sub-fields as artificial intelligence is somewhat problematic, because the Library of Congress classification system does gather all of that subject in one place. General works on computer science, the parent discipline of artificial intelligence are gathered in subclass Q (Q 300-385), and in a subsection of mathematics (QA 76-77). In contrast, applications of computer science tend to be associated with the topics to which computer science and artificial intelligence are applied. Since, however, most of what is covered in this study are the more general kind of work and not associated with other disciplines. The main subclasses used here are subclass Q and QA. Instead of using the term artificial intelligence, therefore, computer science is used throughout this study.

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the third and fifth columns.

[2] The LC classification is arranged under letters of the alphabet. A single letter may, however, cover a series of major classes. There are then commonly indicated by a series of two letter classes, as in this case of Anthropology or by using the single letter as a subclass (besides its use as the letter of an entire schedule section). With respect to the latter, Schedule B, for example, covers Philosophy,

Neuroscience

As defined in the literature of neuroscience, this area is rooted in the classical disciplines of anatomy, physiology, pharmacology, and psychology. In particular, it includes clinical neuropsychology, neurophysiology, and physiological psychology. Yet, neuroscience is not provided separate status as a class with capital letters in the LC classification system. Neuroscience is by subject categories published in the *Journal Citation Reports,* and in particular journal articles (Sengupta, 1989; Kellerman, 1993). Most of neuroscience is formed in the LC subclass RC under neurology and in the subclass QP, physiology; thus, these were used to categorize the area of neuroscience in this research.

Summary of the Cited References in *Cognitive Science*

The total number of the cited references in 329 articles (excluding book reviews) published in *Cognitive Science* for the time periods 1977-1996 was 12,155. Among them, the LC numbers for 10,847 items were located through the use of an on-line catalog and the RLIN Eureka database. The average number of articles published per year, and of cited references per year was 16.5 and 607.7 respectively. The total number of journals cited in *Cognitive Science* consists of approximately 43% (5,208) of the entire set of cited references (12,155). Out of 11,236 published works of 11,236 (which accounted for 92.46 % of the total cited references), a total of 9,415 citations (84% of the total published works) was classified within the six constituent disciplines of cognitive science. A summary of the cited works in the articles published in *Cognitive Science* is shown in Table 3.1.

Psychology, and Religion. But individual subclasses within it for philosophy include both the single letter B and several double letter subclasses.

Table 3.1. Summary of References Cited in *Cognitive Science*

Year	Number of Articles	Total Citations	Published (Percentage)	Unpublished (Percentage)	Journals (Percentage)
1977	15	348	300 (86.21)	48 (13.79)	96 (27.59)
1978	17	307	267 (86.97)	40 (13.03)	72 (23.45)
1979	17	403	338 (83.87)	65 (16.13)	139 (34.49)
1980	17	503	451 (89.66)	52 (10.34)	162 (32.21)
1981	14	339	311 (91.74)	28 (8.26)	110 (32.45)
1982	11	299	268 (89.63)	31 (10.37)	116 (38.80)
1983	12	370	335 (90.54)	35 (9.46)	131 (35.41)
1984	16	606	547 (90.26)	59 (8.09)	279 (46.04)
1985	17	523	461 (88.15)	62 (11.85)	223 (42.64)
1986	17	804	737 (91.55)	68 (8.45)	335 (41.67)
1987	18	560	510 (91.07)	50 (8.93)	230 (41.07)
1988	17	594	561 (94.44)	33 (5.56)	277 (46.63)
1989	20	659	616 (93.47)	43 (6.53)	317 (48.10)
1990	19	777	721 (92.79)	56 (7.21)	343 (44.14)
1991	17	774	726 (93.80)	48 (6.2)	328 (42.38)
1992	16	819	772 (94.26)	47 (5.74)	375 (45.79)
1993	22	880	838 (95.23)	42 (4.77)	420 (47.73)
1994	17	696	672 (96.55)	24 (3.45)	351 (50.43)
1995	15	831	797 (95.91)	34 (4.09)	385 (46.33)
1996	15	1,062	1,010 (95.1)	52 (4.9)	519 (48.87)
Total	**329**	**12,155**	**11,238 (92.46)**	**917 (7.54)**	**5,208 (42.85)**

Each article published in *Cognitive Science* was classified under one of the constituent disciplines to be analyzed for this study. In general, the identification of the subject area of each article was not easy, and groupings tend to be inconsistent, even among professional indexers. Therefore, sources were classified in an objective way, as is often used in other kinds of bibliometric research — by the departmental affiliation of the first author. In this study, if the departmental affiliation of the first author could not be located, the departmental background of the author from the *Dissertation Abstract* (published by UMI) was used. The disciplines which were categorized as "others" include education (17), cognitive science (2), business (2), and physics (2). These were excluded in the analysis this research. The summary of the articles published in *Cognitive Science* according to discipline is shown in Table 3.2.

Table 3.2. Summary of Disciplines of Articles Published in *Cognitive Science*

Discipline	Number of Articles (Percentage)
Anthropology	4 (1.22)
Computer Science	147 (44.68)
Linguistics	15 (4.56)
Neuroscience	7 (2.13)
Philosophy	14 (4.26)
Psychology	118 (35.87)
Others	24 (7.3)

3.1.2. Journal Inter-citation Analysis in Cognitive Science

Since there is no subject category available for cognitive science in any existing classification schemes, journals in cognitive science journals used in this study were selected from a variety of sources. The sources include a set of journals cited in *Cognitive Science* and those that cite *Cognitive Science.* Subject category listings from the ISI index databases and subject headings from other bibliographic databases, such as UNCOVER and RLIN were also used. Eighty five journals were selected for use in the journal citation network. These journals are listed below.

The search for inter-citations required extensive work, and involved searching the three citation index databases, *Arts & Humanities Search*, *Social SciSearch*, and *SciSearch* via the on-line service DIALOG. The search command, for example, is as follows: Select Set for JN = Artificial Intelligence and CW = Cognitive Psychology. This command instructs the system to select all the items in which the journal *Artificial Intelligence* cited *Cognitive Psychology.* Because the abbreviations for CW (Cited Work) were very inconsistent throughout the databases, different abbreviations were entered into the databases for each journal and cited work. In cases where the journals have changed title, the old title and the new one were searched simultaneously. In addition, duplicates in the output of the different databases were from the sets.

Journals Selected for the Journal Citation Network

Anthropology

American Anthropologist
American Ethnologist
Annual Review of Anthropology
Anthropologie
Anthropos
Cultural Anthropology
Current Anthropology
Ethnology
Ethos
Journal of Social and Evolutionary Systems
(*continues *Journal of Social and Biological Structures* from 1992.)
Man (*continued by *Journal of the Royal Institute of Anthropological Institute* from 1995.)

Computer Science

AI Magazine
Applied Intelligence
Applied Artificial Intelligence
Artificial Intelligence
Biological Cybernetics
Communications of the ACM
Computational Intelligence
IEEE Expert
IEEE Transactions on Neural Networks
IEEE Transactions on Pattern Analysis and Machine Intelligence
IEEE Transactions on Systems, Man, and Cybernetics
International Journal of Intelligent Systems
International Journal of Man-Machine Studies
(* continued by *International Journal of Human-Computer Studies* from 1994.)
Knowledge Acquisition
Knowledge Based Systems
Machine Learning
Minds and Machines
Neural Computation

Neural Networks
Neurocomputing
Pattern Recognition

Linguistics

Applied Psycholinguistics
Computational Linguistics
Journal of Child Language
Journal of Linguistics
Journal of Psycholinguistic Research
Journal of Phonetics
Journal of Pragmatics
Language
Language and Cognitive Processes
Linguistics
Linguistic Inquiry
Linguistics and Philosophy
Metaphor and Symbolic Activity
Theoretical Linguistics

Neuroscience

Annual Review of Neuroscience
Behavioral and Brain Sciences
Brain
Brain and Cognition
Cortex
Journal of Cognitive Neuroscience
Journal of Neurophysiology
Journal of Neuroscience
Neuropsychologia
Neuroscience
Trends in Neurosciences

Philosophy

Analysis
Dialectica
Journal of Philosophical Logic
Metaphilosophy
Mind

Monist
Nous
Philosophia
Philosophical Studies
Philosophical Review
Philosophical Psychology
Philosophy and Phenomenological Research
Semiotica

Psychology

Acta Psychologica
Applied Cognitive Psychology (*continues *Human Learning* from 1987.)
Cognition
Cognitive Psychology
Cognitive Neuropsychology
Cognitive Development
Cognitive Science
Developmental Psychology
Journal of Memory and Language
(*continues *Journal of Verbal Learning and Verbal Behavior* from 1985.)
Journal of Mind and Behavior
Journal Experimental Psychology: Human Perception and Performance
Journal Experimental Psychology: General
Memory & Cognition
Psychological Review
Psychological Reports

3.1.3. Journal Co-citation Analysis in Cognitive Science

A search was done on the same databases by using the command for cited works. For example, with the two journals, *Artificial Intelligence* and *Cognitive Science*, Select Set CW = Artificial Intelligence and CW = Cognitive Science, were used, which command a selection that jointly cite anything by *Artificial Intelligence* and anything by *Cognitive Science*. The data set includes 76 journals out of the 85 journals that were selected for the journal citation network. For all possible, n(n-1)/2, unduplicated pairs, there were 2,850 pairs in the data set. The co-citation frequency for the pairs created a symmetric matrix. Nine journals that were excluded, since their total co-citation frequency rate among the other journals was less than 76, the threshold value of which indicated a mean co-citation rate of less than 1.

3.2. METHODOLOGY

Bibliometric methodology has been broadly described in the literature review in Chapter II. In this study, however, it has been necessary to develop a specific method for each research question. During initial explorations, it was found that a singular and uniform method could not be employed to address all questions. Accordingly, the methods of this study tend to be uniquely tied to each question, and are thus associated with the context of each research question.

3.3. RESEARCH QUESTIONS

Owing largely to the lack of a complete interdisciplinary citation methodology, the systematic study of interactions among the disciplines that contribute to cognitive science poses a considerable challenge. Nevertheless, there is a great need for research that can investigate the communication patterns and structure of this interdisciplinary field, and can identify its important literatures. Moreover, since the field has advanced significantly in the last few decades, it is more important to examine trends over an extended time period. This section articulates research questions that will serve to guide efforts to measure the research interactions among the disciplines that contribute to cognitive science.

Constituent Discipline Citation Rates:

1) Do citation rates in *Cognitive Science* exhibit changes over time in terms of proportions of the cited constituent disciplines, and 2) do citation rates change over time in cases where the constituent disciplines cite this journal?

Changes in Disciplinary Citation Rates:

When citation rates among disciplines cited in *Cognitive Science* show fluctuations each year, can the variation of citation rates for each be explained by time changes and the number of articles published for each discipline per year in that journal? Are the citation rates for each discipline citing *Cognitive Science* associated with time changes?

Author Disciplinary Affiliation:

Does the citation rate of the constituent discipline cited by *Cognitive Science* depend on the research area of the authors of each article published in the journal? In other words, do the research areas of the authors who publish the articles influence the nature of citation patterns?

Interdisciplinary Reach:

How frequently do the authors of the articles published in *Cognitive Science* articles refer to materials from outside their own disciplines? When multiple authors from different disciplines collaborate in research, does the research tend to become more interdisciplinary through the use of materials from outside their own disciplines?

Impact of Author's Home Discipline:

Do the home disciplines of authors published in *Cognitive Science* affect their tendency to cite other constituent disciplines, and do these citations vary within the time period? Does the number of disciplines cited in their references differ from discipline to discipline, among each of the six constituent disciplines?

Research Interaction among Disciplines:

Does the citation network of the selected journals in the field of cognitive science exhibit a broad structural change in research interactions among the constituent disciplines of the field of cognitive science over different time periods?

Individual Journal Impact:

Based on the citation network of journals selected for this study, can the influence of each journal in the journal network be isolated and analyzed in its disciplinary and interdisciplinary dimensions?

Journal Status in Network:

Can the status of each journal in the journal citation network be measured in terms of its relative importance to the field of cognitive science?

Co-citations and Internal Structure:

Can co-citation analysis of journals shed light on the internal structure of the field of cognitive science itself?

CHAPTER IV. RESEARCH INTERACTIVITY: CITATION PATTERNS

In accordance with the previous chapter on research design, this chapter reports on the nature and extent of research interactivity in *Cognitive Science* as indicated by citation patterns. These citation patterns cover a 20 year period.

4.1. CONSTITUENT DISCIPLINE CITATION RATES

> *1) Do citation rates in* Cognitive Science *exhibit changes over time in terms of proportions of the cited constituent disciplines and 2) do citation rates change over time where the constituent disciplines cite this journal?*

To examine the changes of citation patterns from 1977 to 1996, the reference sources that were originally aggregated for each year were divided into four different time periods to compare the citation rates for each disciplinary area: 1977-1981, 1982-1986, 1987-1991, and 1992-1996.

1) For the comparison of the overall proportions of cited references for each discipline over the time period, three null hypotheses were formulated:

Hypothesis 1.1: The six constituent disciplines of cognitive science do not differ in terms of the overall proportions of cited references represented in *Cognitive Science*.

Hypothesis 1.2: Citation rates represented in *Cognitive Science* for each time period are not different.

Hypothesis 1.3: There is no interaction between citation rates for the cited disciplines and the time period. The differences in citation rates do not depend on the combination of the levels of the cited disciplines and the levels of the time period.

2) For the comparison of the overall proportions for each discipline that cite Cognitive Science over the time period, three null hypotheses are formulated:

Hypothesis 2.1: The six constituent disciplines of cognitive science do not differ in terms of the overall proportions in which they make reference to *Cognitive Science*.

Hypothesis 2.2: Citation rates for citing disciplines of *Cognitive Science* in each time period are not different.

Hypothesis 2.3: There is no interaction between citation rates of the citing disciplines and the time period. The differences in citation rates do not depend on combining the discipline with the time period.

In the next section, the overall citation patterns for the four time periods, 1977-1981, 1982-1986, 1987-1991, and 1992-1996, will be examined for the cited sources in *Cognitive Science* and the sources citing *Cognitive Science*.

4.1.1 Cited Sources in *Cognitive Science*

Methods

To test the null hypotheses, a two-way analysis of variance (ANOVA) was used. A 4 x 6 factorial experiment with 5 observations per cell (factor level combination) was designed, which included two factors, *discipline* and *time period*. While the factor *discipline* consists of six different levels or categories, *anthropology, philosophy, linguistics, psychology, computer science*, and *neuroscience*, the factor *time period* consists of four different levels, *time1, time2, time 3*, and *time4*. The response variable is the citation rate that is assigned to each of the factor level combinations.

Results

The ANOVA test shows that the first null hypothesis is rejected ($F = 193.37$, $df = 5$, $p < .0001$). It indicates that there is a significant difference among the mean citation rates across the disciplines. The analysis of variance table is given in Table 4.1.1.

Table 4.1.1. ANOVA Table for Discipline by Time Period Two-Way Balanced Design

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Discipline	5	21661.54	4332.31	193.37	0.0001
TIME	3	8.29	2.76	0.12	0.9461
Discipline X TIME	15	975.35	65.02	2.90	0.0008

Since the null hypothesis of equal means for the cited disciplines is rejected, the differences of citation rates among the cited disciplines can be compared. Table 4.1.2 shows the mean citation rates of each discipline and the comparisons among the means using pair-wise t-tests. Overall, psychology represents 37.7 % of the entire references cited in *Cognitive Science*, followed by computer science (25.6%), and linguistics (13.6%). The rest of the disciplines show very marginal proportions: philosophy (4.4%), neuroscience (3%), and anthropology (.7%). When comparing the means closely, the mean rates of psychology, computer science, and linguistics were significantly different from the rest, all at the $\alpha = .05$ level. For philosophy, while the mean difference from computer science, psychology, and anthropology was significant, it was not significantly different from that of neuroscience. The difference between neuroscience and anthropology was not significant, although anthropology was significantly different from the rest of the disciplines.

Table 4.1.2. Multiple Comparisons Using Pair-Wise T-Tests for Cited References

T tests (LSD) for variable: Citation rate
*Means with the same letter are not significantly different at Alpha=0.05.

T Grouping		Mean	N	Discipline
	A	37.631	20	PSY
	B	25.595	20	AI
	C	13.532	20	LING
	D	4.360	20	PHIL
E	D	3.016	20	NS
E		0.714	20	ANTH

*Note: The total of the mean percentage does not add up to 100%, owing to the exclusion of other disciplines that cite the journal.

The ANOVA test shows that the second null hypothesis is not rejected ($F = 0.12$, $df = 3$, $p < .95$). Therefore, there are no significant differences among the mean citation rates of the different time periods. The citation rates tended to be constant in each time period.

The third null hypothesis for interaction is rejected ($F = 2.90$, $df = 15$, $P < 0.0008$). It shows that the interaction effects between the cited disciplines and the time periods are significant. The mean citation rates depend on the combination of the levels of the two factors: discipline and time period.

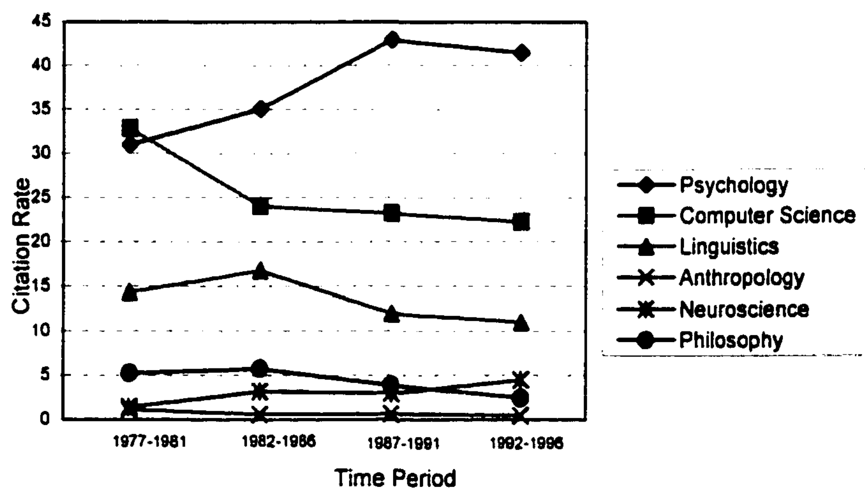
Interaction effects were present between the first time period and psychology, the first time period and computer science, and between the fourth time period and neuroscience. In other words, the citation rates in the first time period were different from the other time period citation rates for psychology and computer science, showing a higher rate for computer science than psychology, compared to the other times. The citation rate for neuroscience in the fourth time period was higher than for the other time periods, showing a higher rate than philosophy. There was also a weak interaction between the second time period and linguistics. The citation rate for linguistics in the second time period was higher than for the other time periods. The interaction effects can also be detected in

Figure 4.1.1, which shows a lack of parallelism among the six plots. Table 4.1.4 shows the sample means for each cell, and the means for each row (discipline) and each column (time period).

Table 4.1.3. Mean Citation Rates for Cited Discipline by Time Period

Discipline	1977-1981	1982-1986	1987-1991	1991-1996	Means
Psychology	31.02	35.07	42.96	41.47	37.63
Computer Science	32.86	24.03	23.22	22.27	25.59
Linguistics	14.36	16.76	11.99	11.02	13.53
Anthropology	1.18	0.59	0.65	0.45	0.71
Neuroscience	1.44	3.19	2.96	4.47	4.36
Philosophy	5.28	5.78	3.90	2.48	3.02
Means	14.44	14.24	14.28	13.69	Grand mean: 14.16

Figure 4.1.1. Mean Citation Rates for Cited Discipline by Time Period.



4.1.2 Citing Sources of *Cognitive Science*

Methods

An experiment was designed to test the mean citation rates for the disciplines citing *Cognitive Science*. Unlike the cited references in *Cognitive*

Science that include different type of sources, the data was collected only for journals that cite *Cognitive Science*. Owing to the incompleteness of psychology journals from the data sources for the time period 1989-1990, those data from 1989 to 1990 were excluded. Therefore, the experiment is a two-way unbalanced design for a 4 x 6 factorial experiment, which included two factors, *discipline* and *time period.*

Results

The ANOVA test shows that the first null hypothesis is rejected ($F = 160.11$, $df = 5$, $p < .0001$). It indicates that there is a significant difference among the mean citation rates of the sources citing *Cognitive Science* for the six constituent disciplines. The analysis of variance table is given in Table 4.1.4.

Table 4.1.4. ANOVA Table for Discipline by Time Period Two-Way Unbalanced Design

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Discipline	5	30353.95	6070.79	160.11	0.0001
TIME	3	1902.95	634.32	16.73	0.0001
Discipline X TIME	15	1658.75	110.58	2.92	0.0010

To compare the differences of the means for each discipline, pair-wise t-tests were used. The mean rates of disciplines that cited *Cognitive Science* included psychology (50.6%), computer science journals (23.05%), linguistics journals (14.94%), philosophy journals (5.49%), neuroscience journals (1.87%), and anthropology (1.523 %). The mean rates of psychology, computer science, and linguistics were significantly different from each other, and from the rest of the disciplines. On the other hand, neuroscience, philosophy, and anthropology were not significantly different from each other, although they are significantly different from psychology, computer science, and linguistics. Table 4.1.5 shows the mean citation rates of each discipline and the comparisons among means using pair-wise t-tests.

Table 4.1.5. Comparisons using pair-wise t-tests for the sources citing *Cognitive Science*

T tests (LSD) for variable: Citation rate
*Means with the same letter are not significantly different at Alpha=0.05.

T Grouping	Mean	N	Discipline
A	50.602	18	PSY
B	23.048	18	AI
C	14.944	18	LING
D	5.485	18	NS
D	1.869	18	PHIL
D	1.523	18	ANTH

* Note: The total of the mean percentage does not add up to 100%, owing to the exclusion of other disciplines that cite the journal.

The second null hypothesis is rejected (F = 16.73, df = 3, $p < .0001$), indicating that there are significant differences among the mean citation rates by the different time periods.

The differences of mean citation rate by the time period were compared using Duncan's multiple range test. The citation rate in the fourth time period was higher than the other time periods, and the second and third time periods were not different from each other. The citation rate in the first time period was lower than for any other time periods. The citation rate of citing sources of *Cognitive Science* has increased over the time period, although the second and third time periods did not show a significant difference.

Table 4.1.6. Duncan's Multiple Range Test for Citation Rate

* Means with the same letter are not significantly different at Alpha= 0.05.

Duncan Grouping	Mean	N	TIME
A	21.383	30	4
B	17.859	18	3
B	16.093	30	2
C	10.291	30	1

The third null hypothesis for testing interaction effects is rejected (F = 2.92, df = 15, P < 0.001), as shown in Table 4.1.6. The results indicated that the interaction effects between discipline and time period were significant. The mean citation rates depended on the combination of the levels of cited disciplines and the different time periods.

The interaction effects were present in the second period (1982-1986) for linguistics. The mean citation rate for linguistics was larger than that for computer science, while it was less than that for computer science in the other time periods. The citation rate of neuroscience has increased considerably in the fourth period (1992-1996). The graph in Figure 4.1.2 shows variation in the means with interaction, showing a lack of parallelism among the plots. The sample means for each cell and row (discipline) and column (time period) means are shown in Table 4.1.7.

Figure 4.1.2. Mean Citation Rates of Citing Sources of *Cognitive Science*

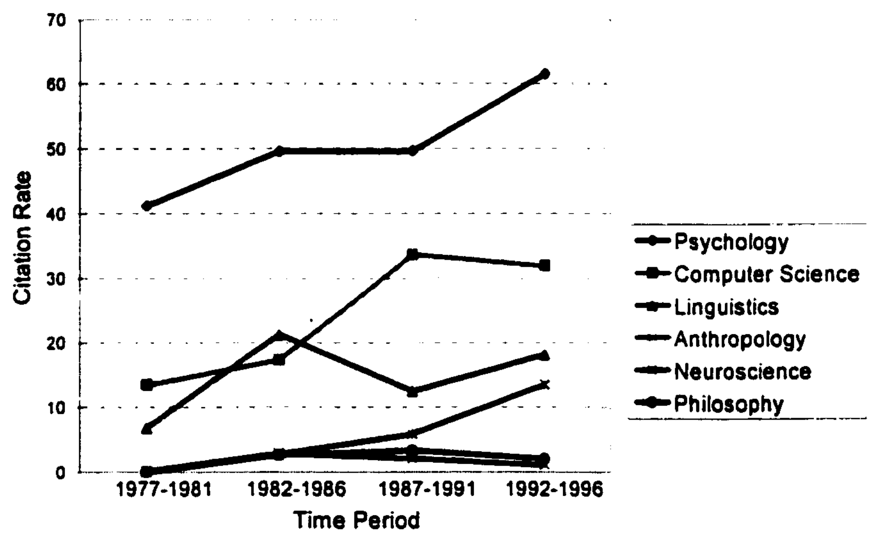


Table 4.1.7. Mean Citation Rates for Discipline by Time Period

Discipline\Time	1977-1981	1982-1986	1987-88, 1991	1992-1996	Means
Psychology	41.19	49.63	49.67	61.54	50.60
Computer Science	13.46	17.33	33.69	31.97	23.05
Linguistics	6.85	21.28	12.50	18.18	14.94
Anthropology	0.25	2.88	2.10	1.09	1.52
Neuroscience	0.00	2.75	5.87	13.47	5.49
Philosophy	5.28	5.78	3.90	2.48	1.87
Means	10.29	16.09	17.85	21.38	Grand Mean: 15.40

Summary

The Pearson product-moment correlation coefficient indicates the following: the citation rates of the constituent disciplines in *Cognitive Science*, and the citation rates where the constituent disciplines cite the journal, were strongly related ($r = .975$ $p < 0.001$).

Psychology was dominant in both samples, followed by computer science, and then linguistics. Philosophy and neuroscience were cited in *Cognitive Science* more than anthropology, although they were not different in the citing sources of *Cognitive Science*. It is noteworthy that neuroscience cited *Cognitive Science* more than philosophy did, in contrast to the cited sources in *Cognitive Science*.

For the cited disciplines in *Cognitive Science* in the first time period (1977-1981) computer science had been cited more than psychology, while psychology was much more cited than computer science in the other time periods. On the other hand, *Cognitive Science* has been cited more in psychology than in the other disciplines during the entire time period. In the second time period (1982-1986), *Cognitive Science* was cited in linguistics more than in computer science (following citations in psychology). By the fourth time period (1992-1996), the citation rate for neuroscience increased considerably, which made the difference between it and linguistics insignificant. The citation rates for neuroscience have increased in both samples, showing a gradual involvement in cognitive science in the third (1987-1991) and fourth time periods (1992-1996). Overall, citation rates in *Cognitive Science* have exhibited changes in terms of the key constituent disciplines that have cited the journal over time.

4.2. CHANGES IN DISCIPLINARY CITATION RATES

When citation rates among disciplines cited in Cognitive Science show fluctuations each year, can the variation of citation rates for each be explained by time changes and the number of articles published for each discipline per year in that journal? Are the citation rates for each discipline citing Cognitive Science associated with time changes?

Hypothesis: The citation rate for each discipline is associated neither with time nor with the number of articles published for each cited discipline in *Cognitive Science.*

$$H_0: \beta_1 = \beta_2 = 0$$

4.2.1 Cited Sources in *Cognitive Science*

Methods

To examine the relationship between a dependent variable (the citation rate for each discipline) and a set of two independent variables (time and the number of articles published in the cited discipline), a multiple regression model was applied to the cited disciplines in *Cognitive Science*. The modeling citation rates as a function of time and of the number of articles published in each discipline, $Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + e$, is conducted in order to test for a linear regression relationship. The overall goodness of fit of the multiple regression model for each discipline is evaluated using an F-test in an analysis of variance format.

Results

Anthropology

The regression parameters β_1 for time and β_2 for the number of articles published in anthropology use in the multiple regression model did not show significance ($p > .17$ for β_1, $p > .11$ for β_2) to explain the variance of the citation rate for anthropology, as shown in Table 4.2.1. The goodness of fit of the model using the F-statistic was tested for the hypothesis ($F = 1.84$, $p > .18$). Therefore, the null hypothesis is not rejected; the variation of citation rates was not dependent on

Table 4.2.1. Analysis of Variance and Regression Parameters for Anthropology

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	2.502	1.251	1.837	0.1895
Error	17	11.559	0.681		
Total	19	14.078			

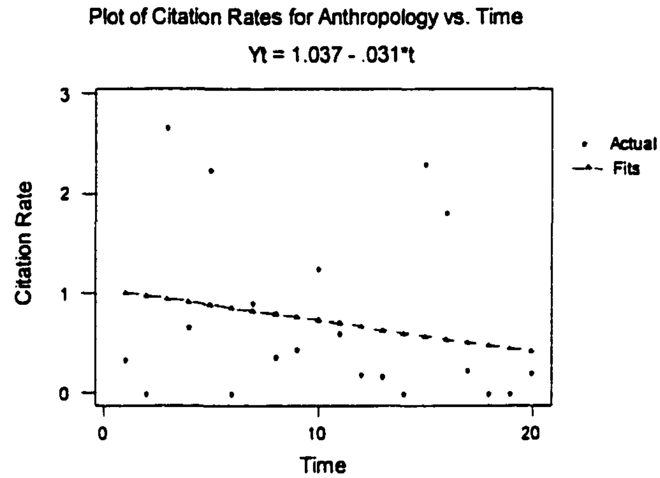
Root MSE 0.825	R-square 0.178	Dep Mean 0.714	Adj R-sq 0.081

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	1.05	0.38	2.747	0.0137
T	1	-0.048	0.03	-1.417	0.1744
CNT	1	0.804	0.48	1.660	0.1153

time nor on the number of articles published for anthropology. The variations of citation rates for anthropology could not be explained by time or the number of articles published for anthropology in *Cognitive Science*. Figure 4.2.1 illustrates the actual citation rate for anthropology and plots a regression line for citation rates over time.

Figure 4.2.1. Linear Regression of Citation Rate by Time for Anthropology



Linguistics

The regression parameters β_1 for time changes and β_2 for the number of articles published in linguistics used in the multiple regression model did not yield a significant degree of relationship with citation rates ($p > .19$ for β_1, $p > .06$ for β_2) at the $\alpha = .05$ level, as shown in Table 4.2.2. The goodness of fit of the model

Table 4.2.2. Analysis of Variance and Regression Parameters for Linguistics

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	163.327	81.664	3.441	0.0556
Error	17	403.498	23.735		
Total	19	566.825			

Root MSE 4.87	R-square 0.288	Dep Mean 13.53	Adj R-sq 0.20

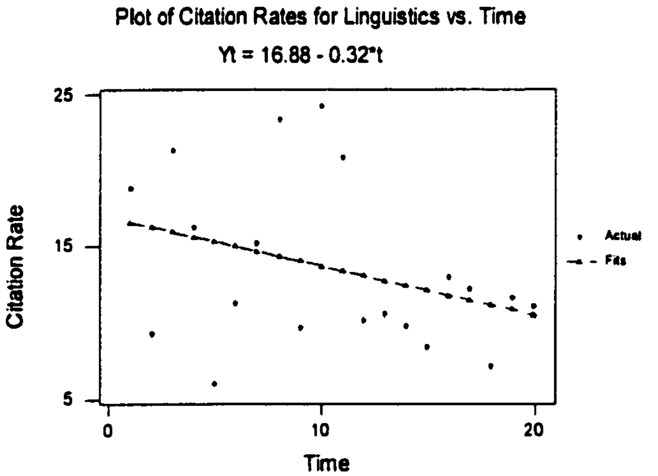
Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	14.228	2.622	5.426	0.0001
T	1	-0.257	0.191	-1.343	0.1970
CNT	1	2.671	1.331	2.006	0.0610

using the F-statistic was tested for the hypothesis ($F = 3.44$, $p > .05$). Therefore, the null hypothesis is not rejected. The variation of citation rates in linguistics was not significantly affected through time or by the number of articles published for linguistics in *Cognitive Science*. This relationship held when both the independent variables (time and the number of articles published for linguistics) were related to the dependent variable of citation rates for linguistics.

However, when only the number of articles published for linguistics was used as a function of the citation rate for linguistics, the regression coefficient ($\beta_1 = 2.96$, $p < .05$) showed that the citation rates for linguistics are significantly related to the number of articles published for linguistics. The citation rate for linguistics tended to increase as the number of articles published for linguistics increased. However, the value of the adjusted coefficient of determination, $\bar{R}^2$, showed that

Figure 4.2.2. Linear Regression of Citation Rate by Time for Linguistics



only 20% of the variation in the citation rate for linguistics was accounted for by the number of articles published for linguistics. Figure 4.2.2 illustrates the actual citation rate for linguistics and plots a regression line for citation rates over time.

Philosophy

The regression parameters β_1 for time changes and β_2 for the number of articles published in philosophy used in the multiple regression model were both significant ($p < .03$ for β_1, $p < .02$ for $\beta2$) at the $\alpha = .05$ level, as shown in Table 4.2.3. The goodness of fit of the model, using the F-statistic, was tested for the

Table 4.2.3. Analysis of Variance and Regression Parameters for Philosophy

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	75.392	37.696	5.718	0.0126
Error	17	112.078	6.593		
Total	19	187.470			

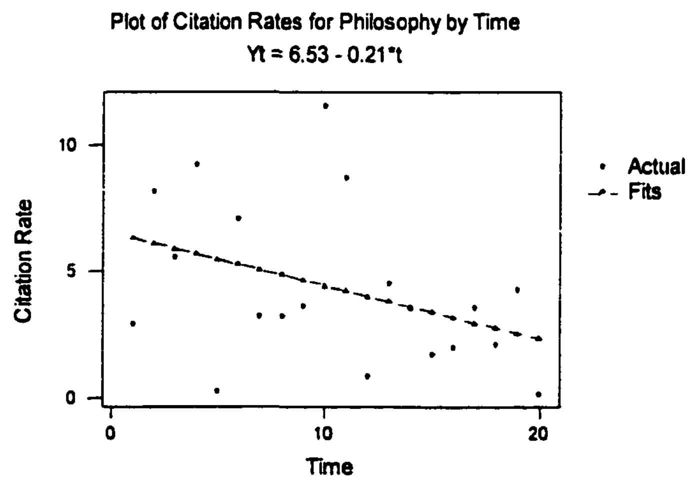
Root MSE 2.57 R-square 0.40 Dep Mean 4.36 Adj R-sq 0.33

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	6.077	1.205	5.043	0.0001
T	1	-0.254	0.101	-2.513	0.0223
CNT	1	1.358	0.509	2.666	0.0163

hypothesis ($F = 5.72$, $p < .02$). Therefore, the null hypothesis is rejected; both variables, time and the number of articles published in philosophy, significantly affect citation rates. The multiple regression model explained 33% of the total

Figure 4.2.3. Linear Regression of Citation Rate by Time for Philosophy



variance in the twenty citation rates ($\bar{R}^2$ = .33). The citation rates for philosophy have decreased over time and the number of philosophy articles published in *Cognitive Science* has also contributed to the decrease of the citation rates. The number of philosophy articles published in *Cognitive Science* was not correlated to the passage of time. Figure 4.2.3 illustrates the actual citation rate for philosophy and plots a regression line for citation rates over time.

Psychology

The regression parameters β_1 for time changes and β_2 for the number of articles published in psychology used in the multiple regression model were both significant ($p < .01$ for β_1, $p < .05$ for β_2) at the $\alpha = .05$ level, as shown in Table

Table 4.2.4. Analysis of Variance and Regression Parameters for Psychology

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	554.112	277.056	15.301	0.0002
Error	17	307.814	18.107		
Total	19	861.927			

Root MSE	4.26	R-square	0.64	Dep Mean	37.63	Adj R-sq	0.60

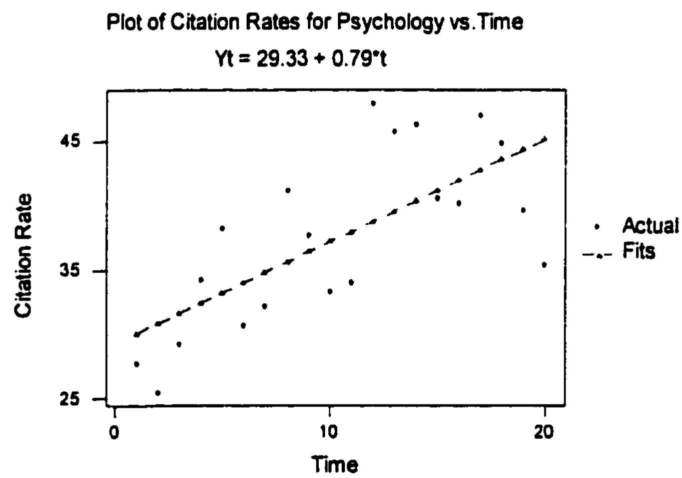
Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	25.345	2.446	10.360	0.0001
T	1	0.553	0.186	2.970	0.0086
CNT	1	1.099	0.397	2.765	0.0133

4.2.4. The goodness of fit of the model using the F-statistic for the null hypothesis was rejected ($F = 15.3$, $p < .01$); the variables, both time and the number of articles published in psychology, significantly affect citation rate. This relationship reveals that both time changes and the number of articles published for psychology contributed to the citation rate for psychology. The multiple regression model explained 60 % of the total variance in the twenty citation rates ($\bar{R}^2$ = .60).

The independent variables, time and the number of articles published for psychology, used in the regression model were interrelated, showing the existence of multicollinearity (Pearson correlation coefficient = .46, $p < .05$). Such multicollinearity provided information for describing and predicting the psychology citation rate overlaps. But the multicollinearity did not appear to lessen the importance of the independent variables in the multiple regression model. The number of articles for psychology tended clearly to increase with the passage of

Figure 4.2.4. Linear Regression of Citation Rate by Time for Psychology



time. Figure 4.2.4 illustrates the actual citation rate for psychology and plots a regression line for citation rates over time.

Computer Science

The regression parameters β_1 for time changes were not significant ($p > .33$); however, the parameter β_2, the number of articles published in computer science used in the multiple regression model was significant ($p < .01$) at the α=.05 level, as shown in Table 4.2.5. Therefore, the null hypothesis was rejected; at least one of the independent variables of time and the number of articles published in computer science significantly affects citation rates. The overall goodness of fit of the model indicated that the overall regression was highly significant ($F = 12.19$, p

Table 4.2.5. Analysis of Variance for the Multiple Regression Model for Computer Science

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	841.708	420.854	12.191	0.0005
Error	17	586.872	34.522		
Total	19	1428.580			

Root MSE 5.876 R-square 0.589 Dep Mean 25.595 Adj R-sq 0.541

Parameter Estimates

Parameter		Standard	T for H0:		
Variable	DF	Estimate	Error	Parameter=0	Prob > |T|
INTERCEPT	1	8.52	7.01	1.215	0.2410
T	1	-0.26	0.26	-0.997	0.3329
CNT	1	2.69	0.71	3.808	0.0014

$< .001$). The multiple regression model explained 54 % of the total variance in the twenty citation rates ($\bar{R}^2 = .54$). It indicated that the number of articles published in computer science contributed significantly to the citation rate for computer science.

In this multiple regression model, the independent variables, time and the number of articles published for computer science, are interrelated (Pearson's correlation coefficient = -.47, $p < .04$), thus showing the existence of multicollinearity: the independent variables provided redundant information in describing and predicting the citation rate for computer science. The regression coefficient of the variable time alone in the simple regression model was significantly related to the citation rates for computer science ($\beta_1 = -.72$, $p < .03$). The multicollinearity caused the independent variable, time, to appear to be less important than it really was.

Overall, the citation rate for computer science has declined over time, as have the number of computer science articles published in cognitive science. Furthermore, both the passage of time and the number of articles published in computer science contributed to the declining citation rate for computer science.

Figure 4.2.5. Linear Regression of Citation Rate by Time for Computer Science

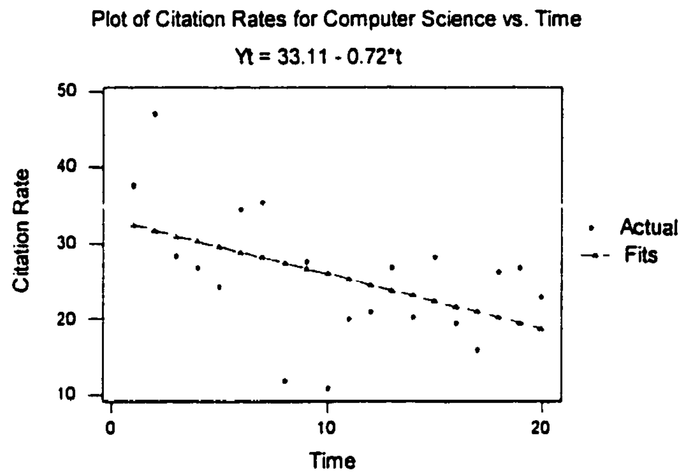


Figure 4.2.5 illustrates the actual citation rate for computer science and plots a regression line for citation rates over time.

Neuroscience

The regression parameters β_2 for the number of articles published for neuroscience were not significant ($p > .05$); however, the parameter β_1, the time changes, of the multiple regression model was significant ($p < .03$) at the $\alpha = .05$

Table 4.2.6. Analysis of Variance and Regression Parameters for Neuroscience

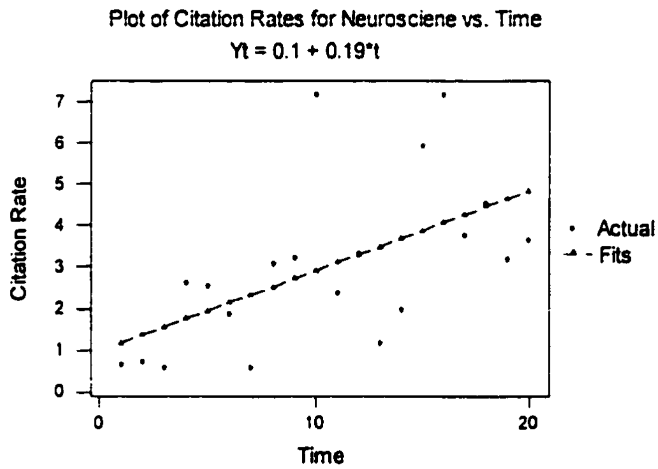
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	35.016	17.508	7.332	0.0051
Error	17	40.593	2.388		
Total	19	75.609			

Root MSE	1.545	R-square	0.463	Dep Mean	3.016	Adj R-sq	0.400

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-7.776	4.440	-1.751	0.0979
T	1	0.147	0.064	2.313	0.0335
CNT	1	1.174	0.562	2.090	0.0519

level, as shown in Table 4.2.6. Therefore, the null hypothesis is rejected; at least one independent variable significantly affects citation rate. The overall goodness of fit of the model indicated that the overall regression is highly significant ($F = 7.33$, $p < .001$). The multiple regression model explained 40 % of the total variance in

Figure 4.2.6. Linear Regression of Citation Rate by Time for Neuroscience



the twenty citation rates ($\bar{R}^2 = .40$). It revealed that both the time changes and the number of articles published in computer science contributed to the increase of the citation rates for computer science. The independent variables, time and the number of articles published for neuroscience were not interrelated (Pearson's correlation coefficient = .34, $p > .14$). Figure 4.2.6 illustrates the actual citation rate for neuroscience and plots a regression line for citation rates over time.

2. Citing Sources of *Cognitive Science*

Methods

A linear model, $Y_t = \beta_0 + \beta_1 t + e_t$, is used in order to identify the nature of variation in citation rates. The existence of variation is tested using the regression coefficients, that is, the slope of a linear model to detect a linear change. However, if the variation is curvilinear, it needs be tested on the second-order or quadratic model, $Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$.

Hypothesis: Citation rates for each discipline neither increase nor decrease as time passes.

H_{01}: $\beta_1 = 0$

When it is appropriate, a quadratic model is used to test the curvature of the model and the general utility of the model using an F-test.

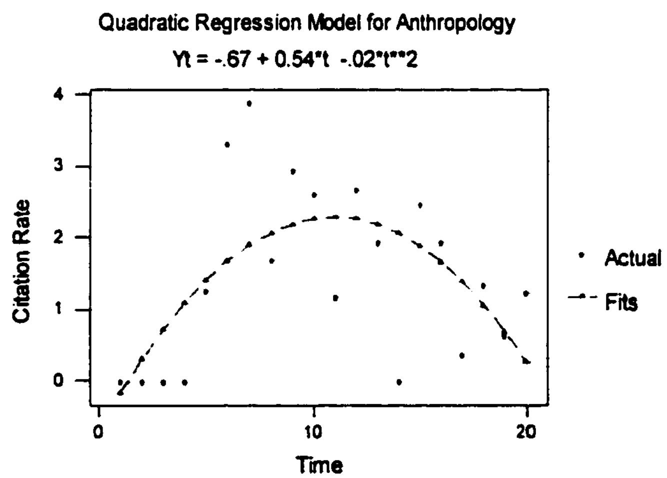
H_{02}: $\beta_1 = \beta_2 = 0$

Results

Anthropology

A linear model does not explain the variation in citation rates adequately ($\beta_1 = .02$ $p > .64$). Furthermore, a linear model does not depict the relationship between the time variable and the citation rate well, showing the determination of the coefficient to be $R^2 = .01$. A second-order model, or quadratic model, $Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$, was found to fit better than the linear model, indicating

Figure 4.2.7. Quadratic Regression for Anthropology



$\bar{R}^2$ =.32. A second-order term t^2 is included in the model ($Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$) because of the curvature in relation to time and the citation rates, as illustrated in Figure 4.2.7. To determine if curvature is present, the null hypothesis, H_{02}: $\beta_2 = 0$,

Table 4.2.7. Analysis of Variance and Regression Parameters for a Quadratic Regression Model for Anthropology

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	11.052	5.526	5.400	0.0153
Error	17	17.395	1.023		
Total	19	28.447			

Root MSE 1.01 R-square 0.39 Dep Mean 1.47 Adj R-sq 0.32

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	-0.673	0.753	-0.894	0.3837
T	1	0.541	0.165	3.280	0.0044
T2	1	-0.025	0.008	-3.235	0.0049

was tested. The significance level corresponded to the quadratic term t^2, and is .0049, as is shown in Table 4.2.7. The global F-test (F = 5.4, df = 2 & 17, p < .02) indicates that the second-order model, $y = \beta_0 + \beta_1 t_1 + \beta_2 t_2 + e_t$, is useful for predicting citation rates. Therefore, the null hypothesis is rejected, indicating that there is a very strong evidence of downward curvature in citation rates over time. Anthropology slightly increased its citing of articles published in *Cognitive Science* up to 1988; afterwards citing decreased.

Linguistics

The hypothesis, H_{01}: $\beta_1 = 0$, is not rejected (β_1 =.44; p > .17). There is insufficient evidence to show that citation rates for linguistics are related to time. The regression parameter estimate for the slope of a linear model indicates that the change of citation rates over the time period is not significant (p > .17). Figure 4.2.8 illustrates graphically the actual data and plots a regression line and Table 4.2.8 shows a correlation coefficient and regression parameter estimates. There is no trend for linguistics in its citation rate.

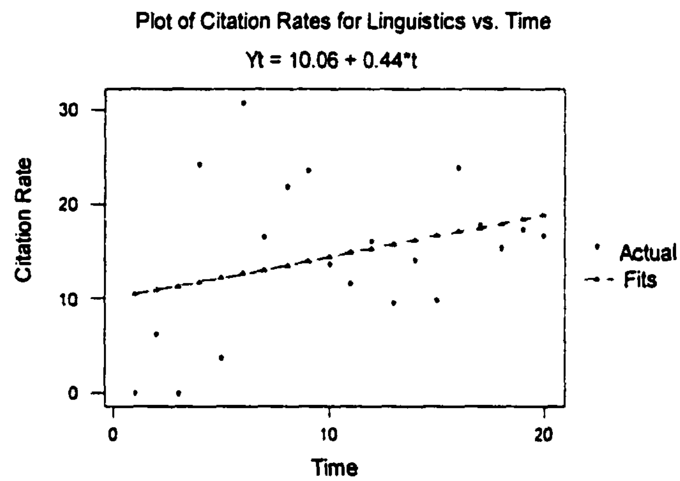
Table 4.2.8. Linear Regression Parameters for Linguistics

Correlation between citation rate and time: r= 0.32, P-Value = 0.18

Regression Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	10.058	3.70	2.716	0.0142
T	1	0.436	0.31	1.410	0.1755

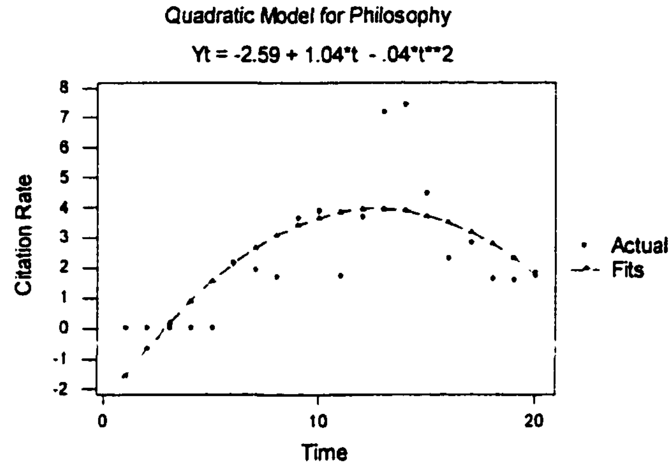
Figure 4.2.8. Linear Regression of the Citation Rates for Linguistics



Philosophy

The null hypothesis, H_{01}: $\beta_1 = 0$, tested via a linear model, is rejected ($\beta_1 = .18$, $p < .034$), thus showing a correlation between time and citation rates for philosophy. However, the coefficient of determination, R^2, indicates that the model does not explain the sample variation in citation rates through use of the time variable ($R^2 = .23$). On the other hand, a quadratic model explains a relationship better than the linear model ($\overline{R}^2 = .50$). A second-order term t^2 is included in the model, because of the regression line curvature in relation to time and citation rate. To determine the validity of the null hypothesis, H_{02}: $\beta_2 = 0$, was tested. In Table 4.2.9, the significance level of the quadratic term t^2 is .0027. The global F-test (F =

Figure 4.2.9. Quadratic Regression of the Citation Rates for Philosophy



10.432, df = 2 & 17, p < .002) of the model indicates that the model is useful for predicting citation rates, as shown in Table 4.2.9. Therefore, the null hypothesis is rejected, indicating there is very strong evidence of downward curvature in the relation between citation rates and time, as illustrated in Figure 4.2.9. The citation rates in philosophy journals that cite *Cognitive Science* has decreased since 1991.

Table 4.2.9. Analysis of Variance and Regression Parameters for Philosophy

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	50.08	25.04	10.43	0.0011
Error	17	40.80	2.40		
Total	19	90.88			

Root MSE 1.55	R-square 0.55	Dep Mean 2.42	Adj R-sq 0.50

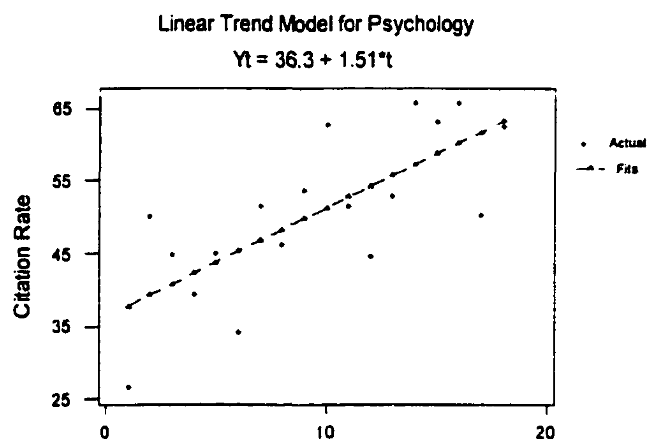
Regression Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	-2.586	1.153	-2.244	0.0385
T	1	1.036	0.253	4.099	0.0007
T2	1	-0.041	0.012	-3.502	0.0027

Psychology

The null hypothesis, H_{01}: $\beta_1 = 0$, is rejected ($\beta_1 = 1.51$; $p < .0005$); there is strong evidence that citation rates for psychology are related to time. The regression parameter estimate for the slope of a linear model indicates that time changes contribute to the prediction of citation rate. Figure 4.2.10 illustrates

Figure 4.2.10. Linear Regression for Psychology



graphically the actual data and a regression line, and Table 4.2.10 shows a correlation coefficient and regression parameter estimates. The citation rate in psychology journals that cite *Cognitive Science* has increased over time.

Table 4.2.10. Linear Regression Parameters for Psychology

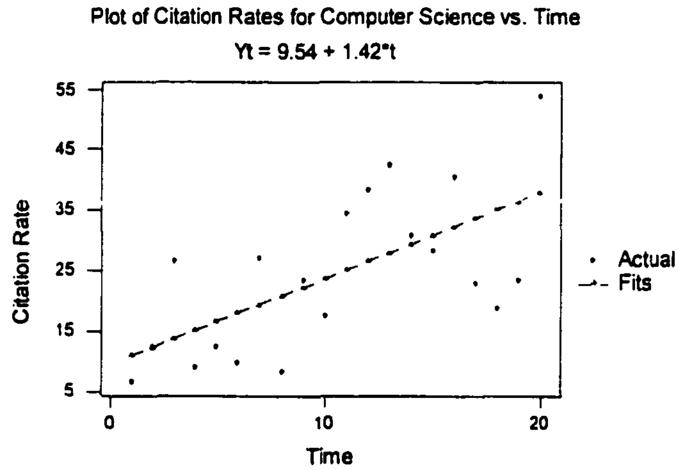
Correlation between citation rate and time: r= 0.74, P-Value = 0.0005
Regression Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	36.297	3.729	9.733	0.0001
T	1	1.506	0.345	4.371	0.0005

Computer Science

The null hypothesis, H_{01}: $\beta_1 = 0$, is rejected ($\beta_1 = 1.42$; $p < .001$), indicating that there is a strong evidence that the citation rate for computer science is related to time changes. The regression parameter estimate for the slope of a linear model indicates that time changes contribute some information for the prediction of citation rates. Figure 4.2.11 illustrates graphically the actual data and a regression line, and Table 4.2.11 shows a correlation coefficient and regression parameter

Figure 4.2.11. Linear Regression for Computer Science



estimates. The citation rates in computer science journals that cite *Cognitive Science* has increased over time.

Table 4.2.11. Linear Regression for the Citation Rates for Computer Science

Correlation between citation rate and time: r= 0.65, P-Value = 0.002
Regression Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	9.539	4.735	2.015	0.0591
T	1	1.415	0.395	3.581	0.0021

Neuroscience

The null hypothesis, H_0: $\beta_1 = 0$, is rejected ($\beta_1 = .85$; $p < .0001$), indicating that there is a strong evidence that the citation rate for neuroscience is related to time. The regression parameter estimate for the slope of the linear model indicates that time changes contribute some information for the prediction of citation rates. ($R^2 = .76$). Figure 4.2.12 illustrates graphically the actual data and a regression line, and Table 4.2.12 shows a correlation coefficient and regression parameter estimates. The citation rate in neuroscience journals that cite *Cognitive Science* has increased over time.

Figure 4.2.12. Linear Regression for the Citation Rates for Neuroscience

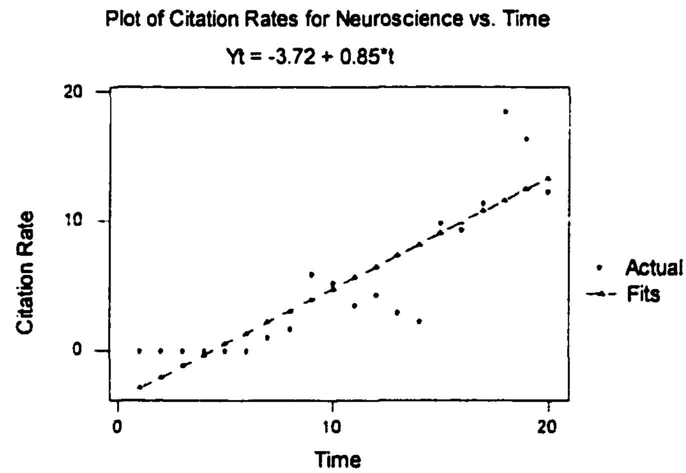


Table 4.2.12. Linear Regression for Neuroscience

Correlation between citation rate and time: r= 0.65, P-Value = 0.002
Regression Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEPT	1	-3.72	1.35	-2.754	0.0131
T	1	0.85	0.11	7.527	0.0001

Summary

Among those disciplines cited in *Cognitive Science*, it was found that the citation rates for philosophy have decreased over time and the number of philosophy articles published in *Cognitive Science* also contributed to the declining citation rates for philosophy. In contrast, the citation rates for psychology have increased over time and these increased citings also depended on the increasing number of psychology articles published in *Cognitive Science*. The citation rates for computer science have decreased over time, with a corresponding apparent reduction in the number of computer science articles published in *Cognitive Science*. The increase also depended on an increased number of neuroscience articles cited in *Cognitive Science*. The analysis of citations to anthropology and linguistics revealed no clear patterns, either through time or by the number of articles published for each in *Cognitive Science*. Overall, then, psychology and neuroscience showed a growth pattern as constituent disciplines, while computer science and philosophy showed a decline pattern as reference disciplines. Anthropology and Linguistics did not show any pattern either through time or by the number of articles cited in each discipline.

With respect to disciplines that cited *Cognitive Science* in their respective literatures, anthropology has increased in its number of citations up to 1988; afterwards it decreased in its number of citations. Likewise, philosophy increased to 1991, then decreased. Psychology, computer science, and neuroscience have continuously increased over time. Linguistics revealed no pattern.

4.3. AUTHOR DISCIPLINARY AFFILIATION

Does the citation rate of the constituent discipline cited by Cognitive Science depend on the research area of the authors of each article published in the journal? In other words, do the research areas of the authors who publish the articles influence the nature of citation patterns?

This question examines whether or not citation rates for the cited disciplines depend on the disciplinary origin of each article published in the journal in terms of citation rates. The origin of each article may be determined by the first author's departmental affiliation.

Hypothesis

H_0: When examining citation rates, there are no interaction effects between the cited disciplines and the nature of the articles published in the journal.

Method

This experiment includes two factors, *discipline* and *departmental affiliation*. Each factor derives from the six disciplines; *anthropology, philosophy, linguistics, psychology*, *computer science*, and *neuroscience*. For the purpose of this study, only articles categorized according to departmental affiliation are included. A 6 x 6 factorial, unbalanced experiment was designed, using the two factors, *discipline* and *departmental affiliation*. The response variable is the citation rate that is assigned to each of the factor level combinations. However, the number of articles published under each departmental affiliation is not equal, which makes this test an unbalanced ANOVA.

Results

The results of the analysis of variance to test the interaction effects revealed that there was a statistically significant interaction among the six departmental

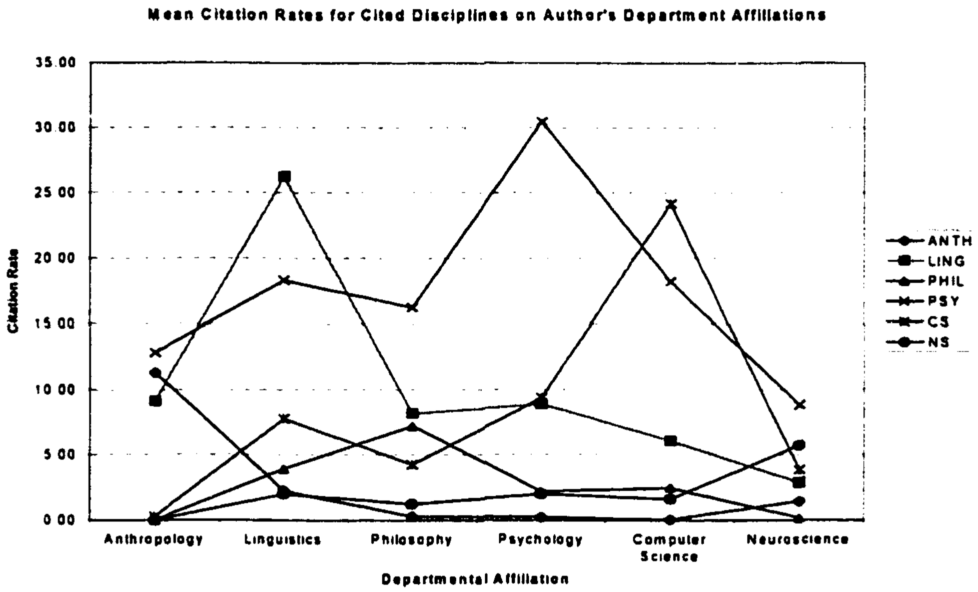
Table 4.3.1. ANOVA Summary for Citation Rates as a function of Departmental Affiliation and Cited Discipline

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Affiliation	5	1917.53	383.51	2.91	0.0126
Discipline	5	12152.40	2430.48	18.47	0.0001
Affiliation X Discipline	25	37618.60	1504.74	11.44	0.0001

affiliations of authors and the six cited disciplines ($F = 11.44$, $df = 25$, $P < 0.0001$), as shown in Table 4.3.1. Therefore, the hypothesis was rejected; the mean citation rates depend on the combination of the levels of two factors: discipline and departmental affiliation.

To help interpret the interaction effects, a graph of a 6 x 6 interaction is given in Figure 4.3.1, which shows a lack of parallelism among the six plots. Table 4.3.2 shows the sample means for each cited discipline against author departmental affiliations. The self-citation rates were high in linguistics, psychology, and computer science. Anthropology, philosophy, and neuroscience cited psychology

Figure 4.3.1. Mean Citation Rates for Cited Disciplines on Authors' Departmental Affiliations



more than their own respective disciplines. Philosophy cited psychology most frequently and linguistics in second place.

Table 4.3.2 Mean Citation Rates for Cited Disciplines on Authors' Departmental Affiliations

Cited Discipline Affiliation	ANTH	LING	PHIL	PSY	CS	NS	Means
Anthropology	11.32	9.14	0.00	12.86	0.29	0.00	5.60
Linguistics	2.26	26.26	3.95	18.35	7.79	2.01	10.10
Philosophy	0.30	8.21	7.26	16.28	4.28	1.25	6.26
Psychology	0.24	8.92	2.21	30.50	9.40	2.04	8.89
Computer Science	0.05	6.09	2.49	18.26	24.19	1.63	8.78
Neuroscience	1.47	2.90	0.18	8.86	3.86	5.76	3.84
Means	2.60	10.25	2.68	17.52	8.30	2.11	Grand mean: 7.25

Summary

The results showed that the difference of citation rates for each constituent discipline depend on the disciplinary origin of the articles published in *Cognitive Science*. The authors who affiliated with anthropology cited from psychology the most frequently, followed by anthropology and linguistics, with computer science receiving only a few citations. The authors affiliated with linguistics cited within their own discipline and psychology more than any other disciplines. Authors affiliated with philosophy cited psychology most frequently, followed by linguistics and philosophy. The authors who affiliated with psychology cited their own discipline the most, followed by computer science and linguistics. The self-citation rates for authors affiliated with computer science were also very high, even though they cited psychology and linguistics moderately. The authors affiliated with neuroscience cited psychology the most, followed by their own discipline and then by computer science.

Overall, the results indicate that the citation rates for the cited disciplines do depend on the disciplinary research areas of the authors who publish articles in *Cognitive Science*. Moreover, the existing subject coverage or editorial policy of *Cognitive Science* can obviously influence which disciplines are cited and how frequently they are cited.

4.4. INTERDISCIPLINARY REACH

How frequently do the authors of the articles published in Cognitive Science articles refer to materials from outside their own disciplines? When multiple authors from different disciplines collaborate in research, does the research tend to become more interdisciplinary through the use of materials from outside their own disciplines?

The interdisciplinary nature of the each article published in *Cognitive Science* is examined through use of the following variables: the rate of using reference sources from outside their own discipline; the number of authors who collaborated in research, and the number of disciplines cited.

Hypothesis 1: The rates of citing sources outside the "home" discipline are not different among the different author groups.

Hypothesis 2: The rates of citing sources outside the "home" discipline are not different among the different groups for the number of disciplines cited.

Hypothesis 3: There is no interaction between the different author groups and the number of disciplines they cite in their citing sources outside the "home" discipline.

Methods

To test the null hypotheses, a 3 x 6 factorial experiment for the unbalanced two-way analysis of variance (ANOVA) was designed. As a response variable, the citation rate outside the home discipline was calculated as a ratio of the percentage citing sources outside the discipline with which an article is affiliated to the total citation rate per article. The two factors were the author group and the number of disciplines cited. The author group was divided into three groups: single author; multiple authors from the same discipline; and multiple authors from the different disciplines. The number of disciplines cited ranged from 2 to 7, thus making up the six levels within the factor.

Results

The interaction between author group and the number of disciplines outside the home discipline cited was not significant ($F = 1.21$, $df = 10$, $p > .28$). Therefore, Hypothesis 3 was not rejected at the .05 level of significance, meaning that the citation rates outside the home discipline do not depend on the combination of different author groups and the number of disciplines cited. The difference in mean citation rates outside the home discipline of the article for each constituent discipline does not depend on the number of disciplines cited in the article.

The results of the ANOVA test showed that the citation rates outside the home discipline were not significantly different among the author groups ($F = 1.66$, $df = 2$, $p > .19$). Therefore, Hypothesis 2 was not rejected, indicating that the number of authors involved in research do not make a difference in the rate of citations outside the author's (home) discipline.

As shown in Table 4.4.1, the results of the ANOVA test showed that the mean rates citing sources outside discipline are significantly different among the number of disciplines cited ($F=4.32$, $df=2$, $p < .0001$). Therefore, Hypothesis 2 was rejected at the $\alpha = .0001$.

Table 4.4.1 Two-way ANOVA Unbalanced Model

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUBCNT	5	8449.76	1689.95	4.32	.0008
AUTHOR	2	1296.09	648.05	1.66	.1928
SUBCNT X AUTHOR	10	4747.08	474.71	1.21	.2821

Using Duncan's multiple range test, Table 4.4.2 compares the mean citation rate outside the home discipline by the number of disciplines cited. The number of

Table 4.4.2. The Mean Citation Rate outside Discipline by the Number of Disciplines Cited

Duncan Grouping		Mean	N	SUBCNT
	A	69.554	6	7
B	A	63.102	29	6
B	A	59.934	69	5
B	A	59.533	104	4
B		54.862	80	3
	C	41.730	17	2

disciplines cited in an article contributes to the citation rate outside the home discipline with respect to author article affiliation. Articles citing two disciplines are significantly different from ones citing seven disciplines. Although the mean rate increased with the number of disciplines, the differences among the number of disciplines from 3 to 6 were not significant.

Summary

The citation rates outside the home discipline of each article were not significantly different among the different author groups. It indicated that the number of authors who collaborated in research does not make a significant difference in the citation rates outside the home discipline.

The citation rates outside the home discipline of each article increased as more disciplines were cited in the article. The results tended to show that the citation rates outside the home discipline represent the interdisciplinary character of each article published in *Cognitive Science*. However, the difference in the mean citation rates outside the home discipline of the articles for each constituent discipline does not depend on the number of authors who collaborate in research, regardless of whether they shared the same discipline.

4.5. IMPACT OF AUTHOR'S HOME DISCIPLINE

Do the home disciplines of authors published in Cognitive Science affect their tendency to cite other constituent disciplines, and do these citations vary within the time period? Does the number of disciplines cited in their references differ from discipline to discipline, among each of the six constituent disciplines?

This question examines how each home discipline cites differently outside of its own discipline at different rates over different time periods. In addition, the interaction effect between the number of disciplines cited in an article and the home discipline of each article in citing outside reference materials is tested in the next section.

Hypotheses

Hypothesis1: Among the constituent disciplines, there is no difference in the rates of citing outside each home discipline.

Hypothesis2: There is no difference in citation rates outside the discipline among the different time periods.

Hypothesis3: The rates of citing outside the home discipline do not depend on the constituent disciplines that publish articles in *Cognitive Science* and the time period

Hypothesis 4: The rates of citing sources outside the home discipline do not depend on the number of disciplines cited in the article and the constituent disciplines that publish articles in *Cognitive Science*.

Results

The two-way ANOVA test indicates that there is no significant interaction between the home disciplines of the articles and the different time periods in citing sources outside the article's home discipline ($F = 1.41$, $df = 13$, $p > .15$). Therefore,

Table 4.5.1. Two-way ANOVA by Departmental Affiliation and Time Period in Citing Outside Materials

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Deparmental Affiliation	5	8155.66	1631.13	4.39	.0007
TIME	3	3775.72	1258.57	3.39	.0186
Affiliation X TIME	13	6818.86	524.53	1.41	.1531

Hypothesis 3 was not rejected at the $\alpha = .05$ level, meaning that the difference in the mean rates of citing sources outside the home discipline for each discipline did not depend on the different time periods.

For the main effects, the ANOVA tests indicate that the percentage of citing sources outside the discipline is significantly different among the disciplines ($F = 4.39$, $df = 5$, $p < .001$), and in different time periods ($F = 3.39$, $df = 3$, $p = < .05$) respectively, as shown in Table 4.5.1. Therefore, both Hypothesis 1 and Hypothesis 2 were rejected.

For multiple comparisons, Duncan's multiple range test was used at the $\alpha = .05$ level. For the home discipline of the article, psychology was significantly different from anthropology, philosophy, and neuroscience, indicating that psychology tends to use its own materials for research, followed by linguistics and computer science.

Table 4.5.2. The Mean Citation Rate of Outside Disciplines by Departmental Affiliations of Authors

* Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	Departmental Affiliation
	A	75.833	4	Anthropology
	A	70.960	14	Philosophy
	A	70.748	7	Neuroscience
B	A	60.730	147	Computer Science
B	A	59.872	15	Linguistics

The rate of citing sources outside the discipline in the first period (1977-1981) was significantly lower than for the second and fourth periods, but not different from the third period. Table 4.5.2 and 4.5.3 show the mean differences

Table 4.5.3. The Mean Citation Rate of Outside Disciplines by Time Period

Duncan Grouping		Mean	N	TIME
	A	61.735	67	2 (1982-1986)
	A	61.144	79	4 (1992-1996)
B	A	55.350	83	3 (1987-1991)
B		54.103	76	1 (1977-1981)

among the disciplines and their respective time periods.

The results of the ANOVA tests for Hypothesis 4 are shown in Table 4.5.4; the null hypothesis not rejected at the α=.05 level (F = 1.41, df = 18, p > .12). It indicates that the difference in the mean rates citing outside reference materials for each discipline did not depend on the number of disciplines cited in the article.

Table 4.5.4. Two-way ANOVA by the Number of Disciplines Cited and Departmental Affiliation

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUBCNT	5	5823.46	1164.69	3.25	.0073
Affiliation	5	7934.77	1586.95	4.42	.0007
SUBCNT X Affiliation	18	9117.40	506.52	1.41	.1247

Summary

In making references outside a home discipline, the discipline with which article authors are affiliated, articles affiliated with psychology were significantly different from those of anthropology, philosophy, and neuroscience. Psychology also had the lowest rates of interdisciplinary borrowing. Psychology tended to use its own materials most for research, followed by linguistics and computer science. It may be that the more internal literature a discipline has to draw upon, the less need it has to go beyond its own boundaries for ideas and problems, and thus the more self-contained it becomes.

The articles published in *Cognitive Science* cited significantly more outside materials in the second time period (1982-1986) than in the first time period, although the citation rates were not significantly different between the other two time periods of 1987-1991 and 1992-1996.

Overall, the results showed that the rates of citing reference material outside an article's home discipline tend to be different in terms of the number of disciplines cited. However, when comparing the disciplines of individual articles with the number of disciplines cited, there were no significant interaction effects revealed in the rates of citing outside sources.

4.6. SUMMARY AND DISCUSSION

The research questions of this chapter investigated the following relationships: 1) the changes of citation rates of the cited constituent disciplines in the journal *Cognitive Science*, and changes of the rate of citing of disciplines included in that journal: 2) the variation of citation rates by time and by the number of articles published for each discipline per year; 3) the differences of citation rates by the author's discipline of the articles published in that journal; 4) the differences of citation rates outside the home discipline of the articles written by different author groups and differences in the number of disciplines cited; and 5) the differences of citation rates outside the author's home discipline for the articles and for the different time periods.

The dependent variable used for the first three questions included the citation rates for the six constituent disciplines, whereas the dependent variable for the last two questions included the citation rates outside the home discipline of the articles published in *Cognitive Science*. The first two questions were related to the citation rates of the cited disciplines and the citing discipline of that journal. The third question examined the citation rates of the constituent disciplines within the author's discipline for the individual articles published in *Cognitive Science*. Question 4 and 5 examined interdisciplinary characteristics of *Cognitive Science* and its individual articles. Unlike other interdisciplinary research (Qin, Lancaster, and Allen, 1997), in which the dependent variable for interdisciplinarity was the number of disciplines cited in an article, the citation rates outside the discipline of each article were used in this study to investigate the interdisciplinarity of the articles published in *Cognitive Science*. It employed an approach similar to the Citations Outside Category (COC) proposed by Porter and Chubin (1985), which served as an indicator for cross-disciplinary research.

Citation rates in cognitive science have exhibited changes in terms of incorporating key constituent disciplines over time. As represented in references to the articles cited in the journal *Cognitive Science*, the initial dominance of computer science gave way to psychology. During the first time period (1977-1981), the cited references in computer science and the articles published in computer science far exceeded those of psychology. Since the second period (1982-1986), psychology commanded the number of citations as well as the number of articles published in *Cognitive Science*, thus establishing its dominance as the key cognitive science discipline, insofar as *Cognitive Science* represents the area of cognitive science.[1]

Linguistics, followed by psychology and computer science, apparently enriched itself as a discipline by drawing on cognitive science both as reference sources in *Cognitive Science*, and by citing sources of *Cognitive Science* during the second period (1982-1986). However, linguistics has decreased gradually its appearance as reference discipline in *Cognitive Science* in the third and fourth time periods (1987-1991 and 1992-1996), but it showed its resurgence as citing sources of *Cognitive Science* in the fourth time period (1992-1996). However, the citation rate for linguistics was related positively to the number of linguistics articles published in *Cognitive Science.*

Philosophy and neuroscience did not show a significant difference as cited and citing disciplines of *Cognitive Science*. However, neuroscience cited *Cognitive Science* more than philosophy did, but was cited less in *Cognitive Science* articles. It is worth noting that the citation rates for neuroscience have increased over time and this increase depended on the number of neuroscience articles published in *Cognitive Science*. Philosophy articles that were published and cited in *Cognitive Science* have decreased over time. Neuroscience itself is a multidisciplinary field, especially as

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[1] During the final phase of this research, results of a similar, comprehensive analysis of the journal *Cognitive Science* was published (Schunn, Crowley, and Okada, 1998). Generally, the results of this study corroborated the findings by Schunn, Crowley, and Okada, and conversely, especially with regard to the domination of cognitive science by psychology and computer science.

represented by cognitive neuroscience, which emerged in the mid-eighties (Johnson, 1997). Cognitive neuroscience has demonstrated an increasingly close interaction with cognitive psychology and clinical neuropsychology (Rugg, 1997). Yet, the appearance of neuroscience in *Cognitive Science* has been gradual and relatively minor.

Anthropology has little involvement in *Cognitive Science* both as a cited and citing discipline, and as indicated by the number of anthropology articles published in *Cognitive Science*. In anthropology, the area of cognitive anthropology was developed from work done in the 1960s on kinship relations; during the 1980s and 1990s it incorporated research on cultural models, reasoning, emotion, memory, motivation and distributed cognition (D'andrade, 1995). Although anthropology has witnessed a constant exchange of ideas across the fields in cognitive science, its appearance in *Cognitive Science* was very limited.

The results reveal that the difference of citation rates for each constituent discipline depends on the research area of the articles published in *Cognitive Science*. Psychology has been the most influential discipline among the constituent disciplines. Authors who affiliated with anthropology, philosophy, and neuroscience have tended to cite psychology more than their own disciplines, whereas those affiliated with psychology, computer science, and linguistics have tended to cite their own disciplines most frequently. Furthermore, the existing editorial policy of *Cognitive Science*, including its subject coverage biases, can influence which disciplines are cited and how frequently they are cited.

As an indicator of interdisciplinary research, the citation rates outside the home discipline of each article were calculated. The calculations were then tested against different variables to see if the individual articles published in the journal *Cognitive Science* represent interdisciplinary dimensions. The citation rates outside the home discipline of each article were not significantly different among the different author groups: single author; multiple authors from the same discipline; and multiple authors from the different disciplines. The results indicate that the number of authors who collaborated in research does not make a significant difference in using material outside their respective home disciplines.

The citation rates outside the home discipline of authors of each article increased as more disciplines were cited in the article. The results indicate that the citation rates outside the home discipline (of the articles published in *Cognitive Science*) tended to represent the interdisciplinary dimension of that journal. However, the citation rate outside the home discipline of each article was not related to the different author groupings and the number of disciplines cited in the article. In the Qin, Lancaster, and Allen study (1997), the degree of interdisciplinarity (which was measured as the number of disciplines cited) differed at different levels of author collaboration. In contrast, in this study, the citation rates outside the home discipline of the article indicated that the rates are differentiated by the number of disciplines cited, but not by the different author groups.

In making references outside the article's home discipline, a difference among the constituent disciplines was found. The articles affiliated with psychology were significantly different from anthropology, philosophy, and neuroscience because they had the lowest rates of interdisciplinary borrowing. Psychology tended to use its own materials the most for its research, followed by linguistics and computer science. It may be the case that the more internal literature a discipline has to draw upon, the less need it has to go beyond its own boundaries for ideas and problems, and thus the more self-contained it becomes. Similarly, the Qin, Lancaster, and Allen study (1997) found significant differences among different scientific disciplines in terms of their degree of interdisciplinarity.

The articles published in *Cognitive Science* cited significantly more outside materials in the second time period (1982-1986) than it did in the first time period, although the citation rates were not significantly different from the other two time periods, 1987-1991 and 1992-1996. However, when comparing the disciplines of individual articles with the number of disciplines cited, there were no significant interaction effects revealed in the rates of citing outside sources.

The subtitle of the journal *Cognitive Science* has changed a few times, thus revealing changes in the journal's interdisciplinary emphasis. The journal's initial subtitle in 1977 was "A multidisciplinary journal of artificial intelligence, psychology, and language." Then, the journal was merged with *Cognition and Brain Theory* in 1985, and its subtitle statement became "Incorporating the Journal *Cognition and Brain Theory*, A Multidisciplinary Journal." It incorporated neuroscience and philosophy in 1988, with the subtitle "A Multidisciplinary Journal of Artificial Intelligence, Linguistics, Neuroscience, Philosophy, Psychology." At the end of 1997, it changed once again to "A Multidisciplinary Journal of Anthropology, Artificial Intelligence, Education, Linguistics, Neuroscience, Philosophy, Psychology."

In reality, seventeen articles related to education were published in *Cognitive Science* from 1977 to 1996. Although education was not included as one of the constituent disciplines of cognitive science in this research, it will make sense to include it as one of the contributing disciplines of cognitive science in future research. In contrast, only four anthropology articles were published in *Cognitive Science* over the 20 years. This reinforces the fact that the proportion of cited references for anthropology was very minimal. Although the journal *Cognition and Brain Theory* was incorporated into *Cognitive Science* in 1985, there were few changes in publishing neuroscience articles. The citation rates of neuroscience as both the cited discipline in *Cognitive Science* and the citing discipline of *Cognitive Science*, have increased slightly in recent years, however.

In sum, the analysis in this chapter has focused on citation patterns of the constituent disciplines of cognitive science, as represented in its central journal *Cognitive Science*. In relative terms, this chapter's approach constitutes *micro-*

analysis. The next chapter presents *macro-analysis*, consisting of broad structural patterns of research interactivity among the constituent disciplines and journals.

CHAPTER V. RESEARCH INTERACTIVITY: STRUCTURAL PATTERNS

This chapter poses four exploratory research questions related to research interactivity, develops a journal network representation, and discusses the findings of an analysis based on a journal citation network.

5.1. RESEARCH INTERACTIONS AMONG DISCIPLINES

Does the citation network of the selected journals in cognitive science exhibit a broad structural change in research interactions among the constituent disciplines of cognitive science over different time periods?

First, the journal network matrices created for this research are described in the following section. Then, measures of research interactivity that are used for describing the interactions among the disciplines are explained, followed by the results.

A Description of the Network Structure of Selected Journals in Cognitive Science

The citation network consisting of selected journals in cognitive science is described in order to obtain a grasp of the overall structure. The citations from four different years were used.[1] For 1994, there is a total of 16,050 citations, which, for the 85 x 85 entries, gives a mean citation rate from journal to journal of 2.22. For 1990, there is a total of 11,844 citations for the 83 x 83 entries with a mean of 1.72

[1] While at the start, every year was to be done, ultimately only four discrete years were used. This was necessary in order to control the cost of the project and amount of data being generated.

from journal to journal. For 1986, a total of 7,771 citations gave a mean citation rate of 1.46 for the 73 x 73 entries. For 1982, there was a total of 6,417 citations for the 63 x 63 entries with a mean citation rate of 1.61. The average mean citation rates for the time periods was 1.76 with variance 0.11, which was distributed within a 95% confidence interval (1.233, 2.28) on the mean rate. As the coverage of journals in the network has increased by introducing new journals, the mean citation rate has gradually increased. At face value, however, the mean citation rate between the journals comprising this network remains more or less stable through the four time periods.

The mean citation rate in the network can be compared with the linkages between the journals to see how densely they are connected throughout the network. The citation linkage between the journals can be measured to see the density of the network structure, and this is calculated as the ratio of the actual number of links to the maximum possible number of links (i.e., 85 x 85 for 1994) in the network. The average citation links between journals is 0.21, showing almost no variation (0.0004), except a slight rise to 0.23 in 1994. The mean citation rate was not correlated with the numbers of citation links ($r = 0.85$; $p = 0.16$). The coefficient was not high enough to have a strong relation between the mean citation rate and citation links. It indicates that citation rates in journals are heavily concentrated in certain journals, but misses links to many other journals.

One way of comparing the structural changes is to measure the correlation of the network in one year with the network in the next year. Raw counts were constructed in a single vector to test if there were any changes made in terms of the raw counts of citations between the network of one year and the next. Only the same journals included in a pair of networks were compared. In terms of correlation, all the possible pairs of networks were related with significance at the 0.0001 level. Table 5.1.1 provides the Pearson product-moment correlation coefficients between different years with a summary of the network structure for each time period. The overall mean for the correlation r was .349, with a range of $r = .197$ between 1982 and 1994, to $r = .764$ between 1990 and 1994. The

Table 5.1.1. Correlation Between Citation Matrices for Different Time Periods and Matrix Structures

Year	Correlation Coefficients			Number of Journals	Total Citations	Mean	Citation Linkage
	1982	1986	1990				
1982	1			64	6,596	1.61	0.21
1986	0.487	1		74	8,131	1.48	0.2
1990	0.206	0.312	1	84	12,585	1.78	0.2
1994	0.197	0.288	0.764	86	17,008	2.3	0.24

correlation between years that are close together tends to be higher than for distant years, including a considerably high correlation between 1990 and 1994. This high correlation between the two years indicates a very similar structure in the number of journals included.

Measures of Research Interactivity

To investigate the interactivity at the level of disciplines rather than at the journal level, the raw citation counts for each discipline were aggregated and divided by the number of journals within each discipline included for each time period, as shown in Tables 5.1.2, 5.1.5, 5.1.8, and 5.1.11 for each time period. Then, the citation matrix was adjusted to reduce the influence of self-citation and, thereafter, to measure the intensity of interaction, according to a measure proposed by Pinski (1980). The adjusted matrix for each time period is shown in Tables 5.1.3, 5.1.6, 5.1.9, and 5.1.12 for each time period.

The citation matrix $C = [c_{ij}]$ indicates the number of references unit i gives to unit j, and the number of citations unit j receives from unit j. Each element c_{ij} of the citation matrix C is divided by the geometric mean of the corresponding diagonal elements c_{ii} and c_{jj}, *i.e.* $r_{ij} = \frac{c_{ij}}{\sqrt{c_{ii}c_{jj}}}$. When measuring the interactivity among the units of a discipline, the interactions from outside its own disciplinary area are involved, and they are placed in the off-diagonals of the matrix. With this adjustment, the size of self-citation in the diagonal (i.e. c_{ii}, c_{jj}.) of the matrix is reduced to 1 and, at the same time, the units in the off-diagonals are adjusted as the degree of self-citation for each discipline. Then, the interactivity is defined as the average of its pair-wise interactivities with each of the other n-1 units, where n is the number of units.

Citing interactivity is defined as the sum of the off-diagonals in the row elements divided by n-1, whereas cited interactivity is defined as the sum of the off-diagonals in the column elements. Citing interactivity represents a measure of how much a discipline makes references to other disciplines, and cited interactivity represents a measure of how much a discipline receives citations from other disciplines. Citing, cited, and average interactivities, and the ratio of the citing and cited interactivity are denoted respectively in the following (Pinski, 1980):

Citing (row) Interactivity: $I_k^{(r)} = \frac{1}{n-1} \sum_{\substack{j=1 \\ j \neq k}}^{n} \frac{c_{kj}}{\sqrt{c_{kk}c_{jj}}}$

Cited (column) Interactivity: $I_k^{(c)} = \frac{1}{n-1} \sum_{\substack{i=1 \\ i \neq k}}^{n} \frac{c_{ik}}{\sqrt{c_{kk}c_{ii}}}$

Average interactivity: $I_k^{(a)} = 1/2\ (I_k^{(r)} + I_k^{(c)})$ Weight= $I_k^{(c)} / I_k^{(r)}$

Pinsky's test showed that the ratio of cited interactivity and citing interactivity (weight) is strongly related with the influence weights proposed by Narin and Pinsky (1976); thus, the ratio is an influence-related measure.

In the next section, the ratio represents a measure of how much a discipline has an influence on the other disciplines in the network. The overall interactivity is the average of the sum of the elements in the adjusted matrix, excluding the diagonal elements. Research interactivity results whenever the overall interactivity is greater than the overall interactivity in this study, it represents engaging in research interactivity. On the other hand, when the overall interactivity is greater than the lower limit of the confidence interval of the overall interactivity but is less than that, it is said to have a marginal interaction.

Results

The overall interactivity for the citation matrix for 1982, 1986, 1990, and 1994 is shown in Tables 5.1.4, 5.1.7, 5.1.10, and 5.1.13. For the four time periods, the overall interactivity measures are, successively, 0.068, 0.067, 0.066, and 0.072. They were stable with the mean 0.068 with almost no variance ($\sigma < .0003$), showing a little increase in 1994. In the next section, the details of the interactions among the disciplines are described for each time period.

<u>Interactivity (1982)</u>

The interactivity patterns for anthropology can be characterized as mainly citing the other disciplines, largely psychology followed by linguistics. In turn, anthropology received marginal citations from philosophy and neuroscience, very minimal citations from linguistics, and did not received any from psychology at all. As a result of a very low cited interactivity (.028) and a high citing interactivity (.099), the ratio of its cited interactivity and its citing is the lowest among the other disciplines.

Linguistics had a higher cited interactivity (.093) than citing interactivity (.081). Linguistics received most references from philosophy, followed by anthropology and psychology. The citing sources of linguistics include mainly psychology, followed by philosophy. The overall influence on the other disciplines in the network was the second highest following psychology.

The interactions of philosophy with other disciplines were characterized as dependent on the other disciplines by making references to them. Its main citing sources were linguistics (.233), followed by the other disciplines, anthropology (.057), psychology (.047), and neuroscience (.012). In turn, philosophy received the most references from linguistics, followed by anthropology, psychology, and neuroscience. There were no interactions made with computer science in this period.

While psychology journals received most references from all the other disciplines, but minimally from philosophy, their references to other disciplines were

Table 5.1.2. The Raw Citation Matrices - 1982

Discipline (1982)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	29	4	1	17	1	2
Linguistics (LING)	1	53	5	16	2	2
Philosophy (PHIL)	2	11	42	3	0	1
Psychology (PSY)	0	5	1	99	1	6
Computer Science (CS)	0	2	0	12	77	13
Neuroscience (NS)	4	3	1	29	4	179

Table 5.1.3. Size-adjusted Citation Matrices - 1982

Discipline (1982)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	1	0.102	0.029	0.317	0.021	0.028
Linguistics (LING)	0.026	1	0.106	0.221	0.031	0.021
Philosophy (PHIL)	0.057	0.233	1	0.047	0.000	0.012
Psychology (PSY)	0.000	0.069	0.016	1	0.011	0.045
Computer Science (CS)	0.000	0.031	0.000	0.137	1	0.111
Neuroscience (NS)	0.056	0.031	0.012	0.218	0.034	1

Table 5.1.4. Measures of Research Interactivity - 1982

Discipline (1982)	Citing	Cited	Average	Weight	Interactivity
Anthropology (ANTH)	0.099	0.028	0.064	0.283	0.067
Linguistics (LING)	0.081	0.093	0.087	1.148	
Philosophy (PHIL)	0.07	0.032	0.051	0.457	
Psychology (PSY)	0.028	0.188	0.108	6.714	
Computer Science (CS)	0.056	0.02	0.038	0.357	
Neuroscience (NS)	0.07	0.043	0.057	0.614	

not significant, except to linguistic journals. Accordingly, the overall ratio of its cited interactivity to its citing interactivity was extremely high (6.714).

Neuroscience made the majority of its references to psychology, and marginal references to anthropology, followed by computer science, linguistics, and philosophy. The major sources of citations were received from computer science, followed by psychology, anthropology, linguistics, and philosophy. The ratio of its cited interactivity and its citing interactivity was the third highest among the disciplines.

The main citing sources for computer science were psychology and neuroscience, followed by linguistics. As mentioned earlier, computer science did not have any transactions with philosophy. It did not make any references to anthropology, though it received some citations from anthropology.

Overall, psychology was the most influential discipline, followed by linguistics, neuroscience, philosophy, computer science, and anthropology in the journal network.

Interactivity (1986)

The citing interactivity for anthropology showed a slight increase from 1982, mostly making references to psychology, linguistics, and philosophy. The citing interaction with philosophy was upgraded to a marginal interactivity, compared to 1982. It received the most citations, but only marginally so from philosophy, followed by linguistics and psychology. The cited pattern with neuroscience disappeared in this period.

For linguistics, there was a slight decrease in citing interactivity and a slight increase in cited interactivity, compared to 1982. In general, the citing patterns remained similar, making references to psychology and philosophy, and receiving citations from philosophy, anthropology, and psychology.

The citing interactivity for philosophy remains the same as in 1982, making references mainly to linguistics journals, followed by anthropology and psychology. The cited interactivity increased with anthropology, compared to 1982. It was most interactive with linguistics in terms of citing and cited interactivity.

The cited interactivity for psychology changed from 1982, receiving most citations from anthropology, followed by neuroscience, linguistics, computer science, and philosophy. The interactivity patterns of psychology with neuroscience changed from 1982, showing more references to neuroscience and receiving more citations from it.

For computer science journals, the citing interactivity remained similar to

Table 5.1.5. The Raw Citation Matrices - 1986

Discipline (1986)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	34	7	2	19	0	2
Linguistics (LING)	1	45	3	11	0	2
Philosophy (PHIL)	2	10	42	3	0	3
Psychology (PSY)	1	9	2	111	2	12
Computer Science (CS)	0	1	0	9	50	6
Neuroscience (NS)	0	2	1	46	9	245

Table 5.1.6. Size-adjusted Citation Matrices - 1986

Discipline (1986)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	1	0.179	0.053	0.309	0.000	0.022
Linguistics (LING)	0.026	1	0.069	0.156	0.000	0.019
Philosophy (PHIL)	0.053	0.230	1	0.044	0.000	0.030
Psychology (PSY)	0.016	0.127	0.029	1	0.027	0.073
Computer Science (CS)	0.000	0.021	0.000	0.121	1	0.054
Neuroscience (NS)	0.000	0.019	0.010	0.279	0.081	1

Table 5.1.7. Measures of Research Interactivity - 1986

Discipline (1986)	Citing	Cited	Average	Weight	Interactivity
Anthropology (Anth)	0.113	0.019	0.066	0.168	0.068
Linguistics (LING)	0.054	0.115	0.085	2.130	
Philosophy (PHIL)	0.071	0.032	0.052	0.451	
Psychology (PSY)	0.055	0.182	0.119	3.309	
Computer Science (CS)	0.039	0.022	0.031	0.564	
Neuroscience (NS)	0.078	0.040	0.059	0.513	

1982, making the most references to psychology, although the citing pattern with neuroscience degraded from a strong interaction (.111) in 1982 to a marginal (.054). On the other hand, the cited interactivity with neuroscience improved strongly.

The major reference sources for neuroscience were psychology and computer science journals. The change of the citing activity with computer science showed a substantial increase, from .034 in 1982 to .081 in 1986. Neuroscience received the most citations from psychology journals in 1986 in contrast to computer science journals in 1982.

Overall, psychology was the most cited discipline, followed by linguistics, computer science, neuroscience, philosophy, and anthropology. Comparisons between 1982 and 1986 show that the influence of computer science on psychology becomes stronger in this period. Psychology made a significant difference in terms of making more references to other disciplines, accordingly increasing citing interactivity from .028 to .055, which made the ratio of cited interactivity to citing interactivity much lower from 6.714 in 1982 to 3.309 in 1986.

Interactivity (1990)

The citing patterns for anthropology have not changed from 1986, although cited interactivity considerably decreased with philosophy and linguistics.

The interactivity patterns for linguistics remained the same as in 1986, making most references to psychology, followed by philosophy, and receiving references from anthropology, philosophy, and psychology.

With some decrease in size, the citing patterns for philosophy generally did not change from 1982, making references mainly to linguistics journals, but marginally to psychology journals. The cited patterns for philosophy remained the same as in 1986, receiving citations mostly from linguistics journals, followed by anthropology.

The citing patterns for psychology remained the same as in 1986, with an increase only with neuroscience from .073 to .094 and a decrease with linguistics from .127 to .095. The cited interactivity changed from 1986, receiving more from linguistics and less from philosophy, neuroscience, computer science, and anthropology. The cited pattern with philosophy decreased from marginal to minimal.

Table 5.1.8. The Raw Citation Matrices - 1990

Discipline (1990)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	42	8	2	18	0	2
Linguistics (LING)	0	58	4	23	1	3
Philosophy (PHIL)	1	7	33	2	0	2
Psychology (PSY)	1	9	1	156	4	18
Computer Science (CS)	0	1	1	14	106	8
Neuroscience (NS)	0	1	0	36	43	234

Table 5.1.9. Size-adjusted Citation Matrices - 1990

Discipline (1990)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	1	0.162	0.054	0.222	0.000	0.020
Linguistics (LING)	0.000	1	0.091	0.242	0.013	0.026
Philosophy (PHIL)	0.027	0.160	1	0.028	0.000	0.023
Psychology (PSY)	0.012	0.095	0.014	1	0.031	0.094
Computer Science (CS)	0.000	0.013	0.017	0.109	1	0.051
Neuroscience (NS)	0.000	0.009	0.000	0.188	0.273	1

Table 5.1.10. Measures of Research Interactivity - 1990

Discipline (1990)	Citing	Cited	Average	Weight	Interactivity
Anthropology (ANTH)	0.008	0.092	0.050	0.087	0.066
Linguistics (LING)	0.088	0.074	0.081	1.189	
Philosophy (PHIL)	0.035	0.047	0.041	0.745	
Psychology (PSY)	0.158	0.049	0.104	3.224	
Computer Science (CS)	0.063	0.038	0.051	1.658	
Neuroscience (NS)	0.043	0.094	0.069	0.457	

The interactivity patterns for computer science journals remained the same as in 1986, making the most references to psychology, followed by neuroscience, and receiving citations mostly from neuroscience.

The overall citing interactivity for neuroscience journals changed from 1986, making most references to computer science, followed by psychology. The cited interactivity for neuroscience journals remained the same as in 1986, with an increase in cited interactivity with psychology journals from .073 to .094.

Overall, psychology was the most cited discipline by the other disciplines, followed by linguistics. But the structure of influence in the network changed: psychology became the most influential, followed by computer science, linguistics, philosophy, neuroscience, and anthropology. The cited activity for computer science journals increased greatly from 0.022 in 1986 to 0.063 in 1990, placing the ratio of cited to citing interactivities in the second place, following psychology journals. On the other hand, the cited activity for linguistics decreased from 0.115 to 0.088, placing that the influence weight behind computer science.

Interactivity (1994)

The interactivity patterns for anthropology did not change from 1990, with most references made to psychology, followed by linguistics, philosophy, and neuroscience, and receiving most references from philosophy, followed by linguistics, and neuroscience.

The citing pattern for linguistics remained the same as in 1990, although the citing interactivity with anthropology increased from 0 to .042. The cited pattern also remained the same as in 1990, receiving most citations from philosophy, followed by anthropology, computer science, psychology, and neuroscience.

The citing interactivity for philosophy with other disciplines increased overall, making most references to linguistics, sufficiently large enough to claim marginal interactions with psychology and anthropology, and minimal interactions with neuroscience and computer science.

Table 5.1.11. The Raw Citation Matrices - 1994

Discipline (1994)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	41	8	2	20	0	2
Linguistics (LING)	2	55	5	22	1	4
Philosophy (PHIL)	2	10	41	6	1	5
Psychology (PSY)	0	14	2	180	6	28
Computer Science (CS)	0	1	2	15	124	15
Neuroscience (NS)	1	4	2	90	24	529

Table 5.1.12. Size-adjusted Citation Matrices - 1994

Discipline (1994)	ANTH	LING	PHIL	PSY	CS	NS
Anthropology (ANTH)	1	0.168	0.049	0.233	0.000	0.014
Linguistics (LING)	0.042	1	0.105	0.221	0.012	0.023
Philosophy (PHIL)	0.049	0.211	1	0.070	0.014	0.034
Psychology (PSY)	0.000	0.141	0.023	1	0.040	0.091
Computer Science (CS)	0.000	0.012	0.028	0.100	1	0.059
Neuroscience (NS)	0.007	0.023	0.014	0.292	0.094	1

Table 5.1.13. Measures of Research Interactivity - 1994

Discipline (1994)	Citing	Cited	Average	Weight	Interactivity
Anthropology (ANTH)	0.093	0.020	0.057	0.215	0.072
Linguistics (LING)	0.081	0.111	0.096	1.370	
Philosophy (PHIL)	0.075	0.044	0.060	0.587	
Psychology (PSY)	0.059	0.183	0.121	3.102	
Computer Science (CS)	0.040	0.032	0.036	0.800	
Neuroscience (NS)	0.096	0.044	0.065	0.512	

The citing patterns for psychology remained the same as in 1990, making most references to linguistics followed by neuroscience. Psychology made slightly more references to computer science and philosophy journals, but none to anthropology. The cited patterns generally also did not change from 1990, maintaining interaction with psychology and a marginal one with computer science.

The interactivity patterns for computer science journals remained the same as in 1990, making most references to psychology, followed by neuroscience, philosophy, linguistics, and receiving most citations from neuroscience, followed by psychology, philosophy, and linguistics.

The citing interactivity for neuroscience changed from 1990, with a decrease with computer science from 0.273 in 1990 to .094 in 1994 and an increase with psychology from .188 to .292. It also increased with the other disciplines, anthropology, linguistics, and philosophy. The cited interactivity for neuroscience remained the same as in 1990, mostly receiving citations from psychology, followed by computer science.

Overall, psychology was the most cited discipline, followed by linguistics, philosophy, neuroscience, computer science, and anthropology. In terms of the ratio of citing and cited interactivities, psychology was the most influential, followed by linguistics, computer science, philosophy, neuroscience, and anthropology.

Graphical Representations of Research Interactivity

A useful way to summarize the overall interactions of the disciplines is in a form of "images matrices" and "reduced graphs" or "image graphs" (Burt, 1982; Doreian and Fararo, 1985) in which binary elements for the interactions between the discipline areas are used to compare the relations in a network. This method is adopted from social network analysis in order to display the interactivity based on the measures derived in the journal network. In general, the network structural properties are translated into the dual notions of social position and social role. The position is a set of blocks categorized by individual actors' structural similarities, while the role refers to patterns of relations between the actors or positions in multi-relational networks. In this study, the positions as a group of journals categorized into discipline areas in the network were pre-determined by aggregating the journal references to other journals at the discipline level. The role can be interpreted as the citing and cited relations between the discipline areas. These methods can give a powerful representation to simplify patterns in complex network data, such as in a journal citation network, to reveal the nature of the relations embedded in the network. The measure of research interactivity in the size-adjusted matrices for each time period is used to compare citation relations between the disciplinary areas.

The mean of the interactivity measures of each citation matrix, i.e., the overall interactivity, is used as a cutoff point, where the measure above the cutoff is coded as 1 and that under it is coded as 0 in image matrices. In this way, however, the image structures make use of a filter which removes the extent to which they can be related marginally or insignificantly. For the disciplines whose interactions are absent or weakly connected in the network, the image structures were modified to represent them as the cutoff point at a lower limit of 95% t-confidence interval for the overall interactivity, shown as an asterisk (*) in the matrices in Figures 5.1.2 - 5.1.5. The measure of interactivity is also illustrated as graphs, where each node represents the disciplinary area and the direct edges display the relations or interactions between the nodes, i.e., the discipline areas. The direct edges will be connected as a straight line for 1 and a dotted line for an asterisk (*). Figures 5.1.2 - 5.1.5 provide the reduced graphs or image graphs based on the image matrices for each time period. Despite the simple descriptions of observed relations, the image structures represent the relations in a form suited to more vivid comparisons across the networks. In the next section, research interactivity for each time period is summarized, based on the image matrices and graphs. Figure 5.1.1 describes the overview of the research interactivity.

Summary of Research Interactivity

Among the disciplines included in the journal inter-citation network, psychology was the center for research interactivity throughout the four time periods, 1982, 1986, 1990, and 1994. The cited interactivity patterns for psychology were consistent with neuroscience, anthropology, computer science and linguistics for the four time periods. With philosophy, it became stronger in 1994 than in the other years, showing a weak interactivity in 1982 and 1986. It indicated that psychology was consistently the most influential on the other disciplines. The citing interactivity for psychology was consistent with linguistics throughout the time periods, whereas the one with neuroscience became strong from the second period onward. In 1982, psychology was very conservative in citing sources from the other disciplines, although it had a great impact on the other disciplines as a feeder in cognitive science.

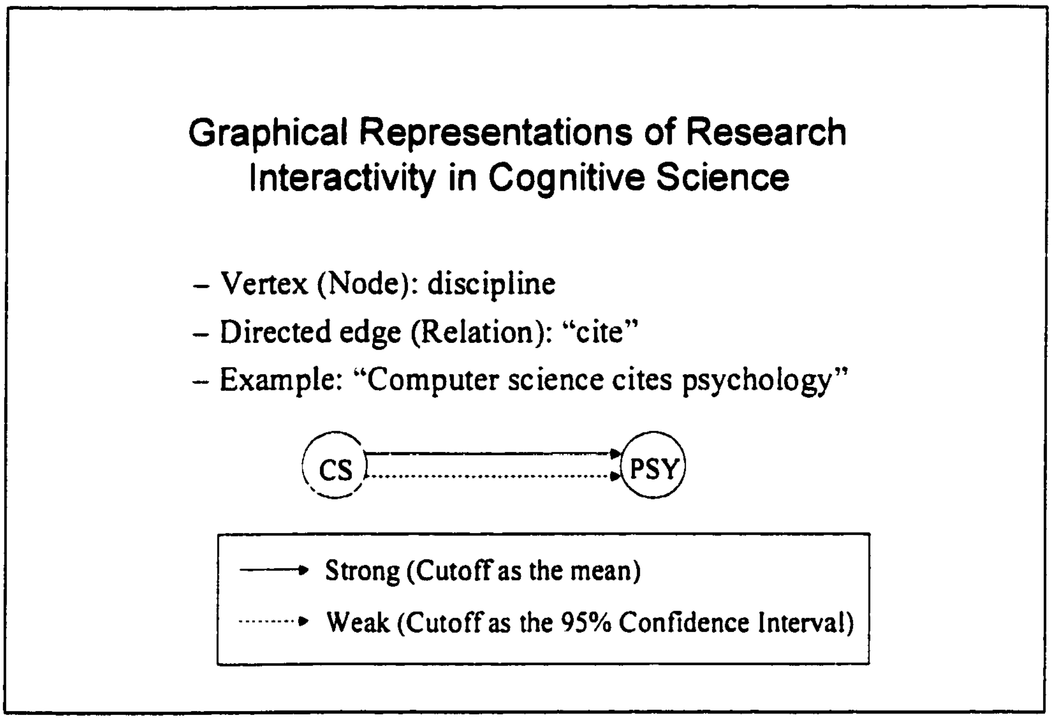
The citation patterns between neuroscience and computer science remain consistent, neuroscience making references to computer science journals and receiving marginal citations from computer science. The citing interactivity of neuroscience with computer science increased until 1990, while the cited interactivity decreased slightly over the time period. It showed a weak citing interactivity of neuroscience with anthropology in 1982.

Philosophy had a strong interaction with linguistics throughout the time period, although it showed that the citing interactivity of linguistics with philosophy was very minimal in 1982. With anthropology, philosophy showed a weak citing and cited interactivity.

Linguistics had a strong interaction with psychology, as indicated before. It had an influence on anthropology constantly. Anthropology mainly cited from the other disciplines, specifically psychology, linguistics, and marginally from philosophy. It had a consistent, but weak interaction with philosophy in 1986 and 1994. Throughout the four time periods, the interactivity of anthropology was the lowest in the network.

In summary, although the interactions among the disciplines in 1982 were rather confined in certain disciplines except those with psychology, the analysis showed a stability of the network, with very similar research interactivity patterns among the disciplines.

Figure 5.1.1. Graphical Representations of Research Interactivity



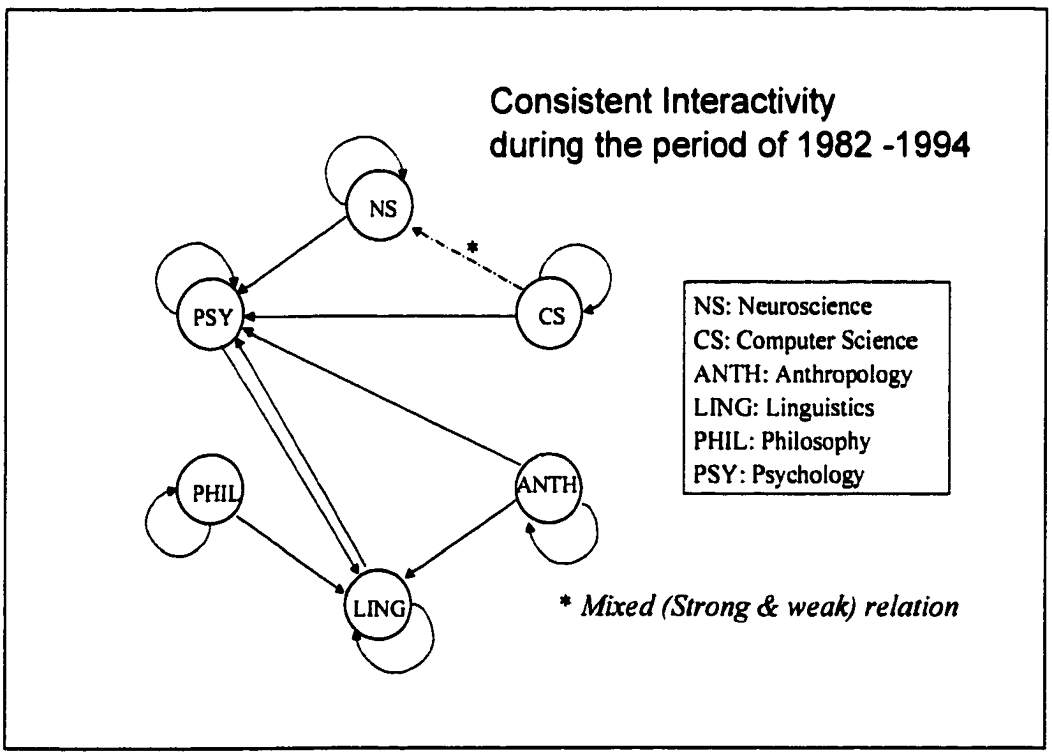
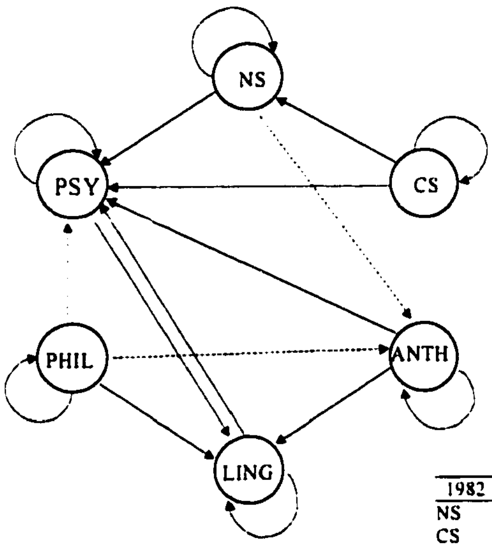


Figure 5.1.2. Research Activity - Image Graph and Matrix for 1982

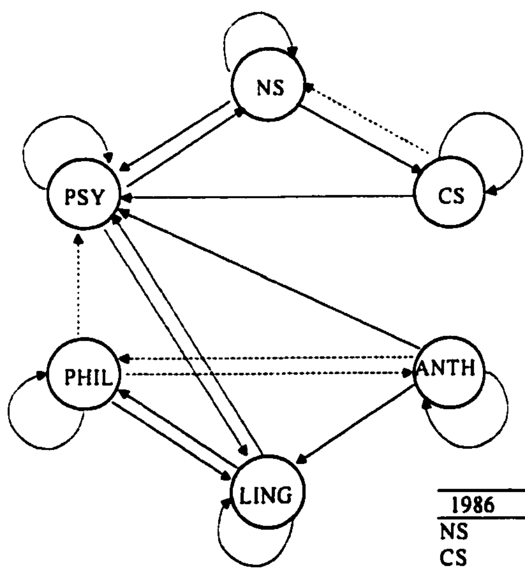


1982

NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

1982	NS	CS	ANTH	LING	PHIL	PSY
NS	1	0	•	0	0	1
CS	1	1	0	0	0	1
ANTH	0	0	1	1	0	1
LING	0	0	0	1	0	1
PHIL	0	0	•	1	1	•
PSY	0	0	0	1	0	1

Figure 5.1.3. Research Activity - Image Graph and Matrix for 1986

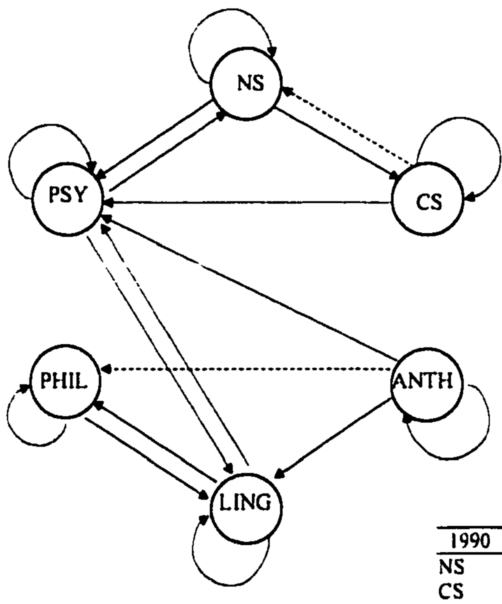


1986

NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

1986	NS	CS	ANTH	LING	PHIL	PSY
NS	1	1	0	0	0	1
CS	•	1	0	0	0	1
ANTH	0	0	1	1	•	1
LING	0	0	0	1	1	1
PHIL	0	0	•	1	1	•
PSY	1	0	0	1	0	1

Figure 5.1.4. Research Activity - Image Graph and Matrix for 1990

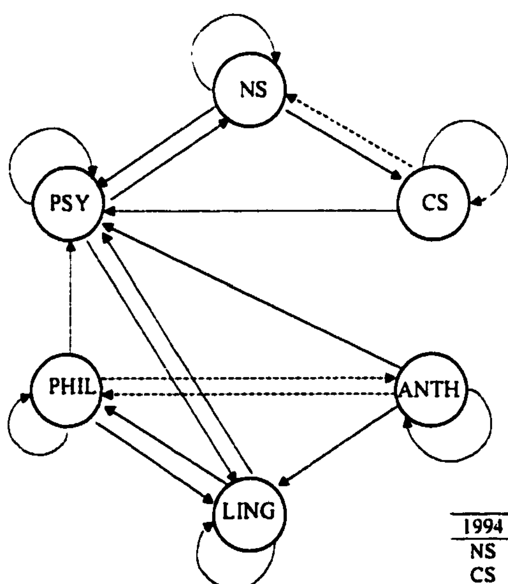


1990

NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

1990	NS	CS	ANTH	LING	PHIL	PSY
NS	1	1	0	0	0	1
CS	*	1	0	0	0	1
ANTH	0	0	1	1	*	1
LING	0	0	0	1	1	1
PHIL	0	0	0	1	1	0
PSY	1	0	0	1	0	1

Figure 5.1.5. Research Activity - Image Graph and Matrix for 1994



1994

NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

1994	NS	CS	ANTH	LING	PHIL	PSY
NS	1	1	0	0	0	1
CS	*	1	0	0	0	1
ANTH	0	0	1	1	*	1
LING	0	0	0	1	1	1
PHIL	0	0	*	1	1	0
PSY	1	0	0	1	0	1

5.2. INDIVIDUAL JOURNAL IMPACT

Based on the citation network of journals selected for this study, can the influence of each journal in the journal network be isolated and analyzed in its disciplinary and interdisciplinary dimensions?

In the previous section, the research interactivity was examined at the discipline level. The individual journals were aggregated into disciplines in order to see the overall interactions among the disciplines. In this section, the importance of each journal is measured to examine its status in the network. Based on the Salancik's (1986) importance measures of journals in a dependency network, the overall importance of a journal in the network was partitioned into a subgroup, i.e., *discipline*, to identify the roles of the journals in the entire network. Based on their importance, the journals were initially assigned to six different disciplines in order to isolate the contribution of each one to the other disciplines. This arrangement would show the extent to which a journal's influence was concentrated in one particular discipline or spread out to the other disciplines in the network at the same time, it is possible to isolate the influence of any journal within a certain subgroup. The importance of the journals whose disciplines were predetermined to begin with was partitioned into six disciplines to isolate its contribution to each of the disciplines. Therefore, it would know how much influence of a journal is concentrated within a particular discipline or spread out to the other disciplines in the network. At the same time, journals influencing in a certain subgroup can be isolated.

Methods

Based on the overall importance measure (Salancik, 1986) explained in Chapter II, $IMP_i = [D]_{ij}\, IMP_i + INT_i$, (1.1) where $IMP_i = [I - D_{ij}]^{-1} * INT_i$ (1.2) using

Leontif's inversion, the journals were assigned to subgroups, i.e. discipline. The intrinsic value for journal i, INT_i, is substituted with $[M]_{ik} * S_k$, (1.3) where $[M]_{ik}$ is a matrix representing a journal *i*'s membership with discipline *k* and S_k is a vector of intrinsic value attributed to *k* disciplines. The structural importance of member journals for each discipline is derived by extracting the transaction component resulting from subtracting INT from IMP, [IMP - INT]. Equations (1.2) and (1.3) are substituted with $[I - D_{ij}]^{-1} * [M]_{ik} * S_k - [M] * S_k$. If the vector [S] is a (k x k) diagonal matrix, with S_k in the diagonals and zeros elsewhere in the matrix, the importance of a journal for the k disciplines is shown as $[SI]_{ik} = [I - D]^{-1} * [M] * [S]_{kk}$. It is derived as $[SI] = [I - D]^{-1} * [D] * [M] * [S]$, where [D] is the (*i* x *i*) dependency matrix, M is the (*i* x *k*) matrix representing each journal's membership in a discipline, and S is the (*k* x *k*) diagonal matrix of intrinsic value attached to each discipline. Here, S is assumed as 1 and can be eliminated.

Results

The figures in Appendix II can be reviewed either across columns or across rows. The headings indicate disciplines and the journals of the disciplines are identified by an asterisk. The figures in the column indicate each journal's structural influence on the journals of the discipline. The figures across the row indicate the distribution of the total influence of the journal throughout the disciplines. The mean importance index within a discipline area was used as a cutoff point to identify the structural influence of the journals within a disciplinary area of the network in the next section.

Neuroscience

1982

Journal of Neuroscience was the most influential journal and outstanding among other influential journals in Neuroscience, in which its variance (0.001) of the mean index value in neuroscience is higher than the other years. Including *Psychological Review*, which was the fifth influential journal, there were 7 other psychology journals influential on the neuroscience journals. Among the influential journals in neuroscience, *Brain* and *Behavioral and Brain Sciences* were most interactive with other disciplines, by spreading out their influence to other disciplines. While the influence of *Brain* spread out to linguistics and philosophy, that of *Behavioral and Brain Sciences* spread out to anthropology, computer science, and psychology. The influence of *Neuropsychologia* was distributed to psychology.

<u>1986</u>

The overall measure had little variance (0.0002) among the influential journals. *Brain* was the most influential journal and its influence was distributed across computer science, philosophy, and psychology. The influence of *Cortex* and *Neuropsychologia* was spread out to psychology. Including *Psychological Review*, seven other psychology journals were influential in neuroscience.

<u>1990</u>

Neuropsychologia was the most influential in neuroscience in 1990. While *Journal of Neurophysiology* was influential on computer science and linguistics journals, *Biological Cybernetics* in computer science was influential on neuroscience journals. A majority of psychology journals shoed an influence on neuroscience.

Among the influential neuroscience journals, *Brain* was influential on linguistics, philosophy, and psychology. *Behavioral and Brain Sciences* had an influence on anthropology, linguistics, and philosophy, and psychology.

1994

Journal of Neuroscience was the most influential journal on neuroscience in 1994. Influential journals on neuroscience included 9 other neuroscience journals, 9 psychology journals, and 1 computer science journal. *Behavioral and Brain Sciences* was influential on anthropology, linguistics, philosophy, and psychology. *Biological Cybernetics* in computer science was influential on neuroscience as it was in 1990.

Summary

Overall, *Behavioral and Brain Sciences* and *Brain* in neuroscience were interactive with other disciplines throughout the time period. *Brain* had an influence on linguistics, philosophy, and psychology, whereas *Behavioral and Brain* Sciences had an influence on anthropology, linguistics, philosophy, psychology, and computer science. Important neuroscience journals were *Journal of Neuroscience, Journal of Cognitive Neuroscience, Brain, Neuropsychologia, Journal of Neurophysiology, Cortex, Behavioral and Brain Sciences, Neuroscience,* and *Trends in Neurosciences*. Among the influential psychology journals on neuroscience, *Psychological Review* was the most influential, followed by *ACTA Psychologica, Cognitive Psychology, Cognition, Journal of experimental Psychology-Human Perception and Performance,* and *Journal Experimental Psychology-General.*

This structural influence of psychology on neuroscience reflects the result of the overall research interactivity shown in the previous section, showing some influence by psychology and computer science.

Computer Science

1982

There were only five journals in computer science included in the network. In this time period, the scarcity of the computer science journals entered in the network contributed to the structural influence from the other disciplines: psychology, neuroscience, and linguistics. *Psychological Review* was the most influential journal, followed by *Behavioral and Brain Sciences* and *Communications of the ACM.* The linguistics journals *Linguistic Inquiry, Language,* and *Linguistic Inquiry* were among the influential journals on computer science. Especially *Behavioral and Brain Sciences* was more influential on computer science than on its own discipline, neuroscience. On the other hand, *Artificial Intelligence*'s influence in the network was spread out to psychology, computer science, and linguistics.

1986

Three computer science journals *IEEE Transactions on Pattern and Machine Intelligence*, *Communications of the ACM*, and *Artificial Intelligence* were the most influential, followed by journals from psychology, neuroscience and linguistics. The rest of the influential journals were *Psychological Review, Journal of Neurophysiology, Cognitive Science, Cognitive Psychology, Journal of Memory and Language, NS, Behavioral and Brain Sciences, Biological Cybernetics, Linguistics, Memory & Language, Brain,* and *International Journal of Man-Machine Studies.*

1990

Artificial Intelligence was the most influential, followed by *Communication of the ACM* and *Cognitive Science*. *Cognitive Science* appeared more influencial on computer science than on psychology and also surpassed its influence over *Psychological Review* in this time period. In addition, there were five other neuroscience journals, including *Journal of Neurophysiology, Behavioral and Brain Sciences, Journal of Neuroscience, Trends in Neurosciences,* and *Annual Review of Neuroscience*, and four other psychology journals, including *Psychological Review, Cognitive Psychology, Cognition,* and *Journal of Experimental Psychology - Human Perception and Performance*, influential on computer science.

Among the influential computer science journals, the influence of *Artificial Intelligence* was distributed to psychology, whereas that of *Biological Cybernetics* concentrated on neuroscience.

1994

Artificial Intelligence was the most influential journal, followed by *Cognitive Science*, *Communication of the ACM.* There were four neuroscience journals, including *Behavioral and Brain Sciences, Journal of Neurophysiology,* and *Journal of Neuroscience*, and three other psychology journals, including *Psychological Review*, *Cognition*, and *Cognitive Psychology*, that were influential on computer science. Among the influential computer science journals, as in 1990, the influence of *Artificial Intelligence* was distributed to psychology, whereas that of *Biological Cybernetics* was spread to neuroscience. *Communication of the ACM* was an influential source on linguistics.

Summary

Throughout the time period, *Artificial Intelligence* had consistent influence not only on computer science, but also on psychology. The influence of *Biological*

Cybernetics on neuroscience has increased over the time period. Journals in psychology and neuroscience were important sources for computer science.

Anthropology

1982

American Ethnologist and *Journal of Memory and Language* from psychology were equally influential, including six other anthropology journals, *Man, Ethnologist, Current Anthropology, Annual Review of Anthropology, Anthropos,* and *Ethos*. Other influential journals on anthropology include two linguistics journals, *Journal of Linguistics,* and *Language*, four more psychology journals, *Psychological Review, Cognitive Psychology, Memory & Language, Cognition*, and one neuroscience journal, *Behavioral and Brain Sciences*. The influence of the journals concentrated on its own discipline, anthropology, except the journal *Man,* which had influence on philosophy.

1986

American Ethnologist was the most influential journal, followed by *Man* and *Journal of Memory and Language* from psychology. Others include three linguistics journals, *Language, Journal of Linguistics, Linguistics Inquiry*, six other anthropology journals, *Annual Review of Anthropology, Ethnology, Current Anthropology, Ethos, Anthropos*, and *Anthropologie*, five other psychology journals, *Psychological Review, Memory & Language, Cognitive Psychology, Cognition,* and *Cognitive Science*, and one neuroscience journal, *Behavioral and Brain Sciences*. As was in 1982, the anthropology journals were concentrated within its discipline, except the journal *Man,* which was influential on philosophy.

1990

The top four journals were *American Ethnologist, Current Anthropology, MAN* and *Annual Review of Anthropology.* Others included seven psychology journals, *Journal of Memory and Language, Psychological Review, Memory & Language, Cognition, Cognitive Psychology, Journal of Experimental Psychology - General,* and *Journal of Experimental Psychology - Human Perception and Performance*, two Linguistics journals *Journal of Linguistics* and *Language*, one neuroscience journal, *Behavioral and Brain Sciences,* and one philosophy journal, *Semiotica. Man* was the only journal influencing outside the discipline, philosophy, showing a consistent trend from the previous time periods.

1994

The top four journals, *American Ethnologist, Current Anthropology, Man* and *Annual Review of Anthropology* remained the same as in 1986, followed by *Cultural Anthropology* and *Ethnology*. There were three linguistics journals, *Language, Journal of Linguistics,* and *Language and Cognitive Processes*, seven psychology journals, *Psychological Review, Memory & Language, Journal of Memory and Language, Cognitive Psychology, Cognition, Journal of Experimental Psychology - General,* and *Cognitive Science*, one neuroscience journal, *Behavioral and Brain Sciences*, and one philosophy journal, *Mind,* that were influential on anthropology. The anthropology journals were influential on its own discipline; the journal *Man* had a marginal influence on philosophy.

Summary

The journals, *American Ethnologist, Current Anthropology, Man*, and *Annual Review of Anthropology*, including *Journal of Memory and Language* from psychology were the influential journals in anthropology. The anthropology journals were influenced by journals from the other disciplines, psychology, linguistics, philosophy, and neuroscience. However, its influence did not reach the other disciplines throughout the time periods, except one journal *Man,* which had influence on philosophy.

Linguistics

1982

The top three influential journals were *Language, Linguistics,* and *Linguistics Inquiry.* Other influential journals included five psychology journals *Cognitive Psychology, Journal of Memory and Language. Cognition Psychological Review*, and *Memory & Language*, four more linguistics journals *Journal of Linguistics, Journal of Child Language, Journal of Psycholinguistic Research,* and *Linguistics and Philosophy*, two philosophy journals, *Mind* and *Philosophical Review.* While *Journal of Linguistics* and *Language* had an influence on anthropology, the influence of *Linguistics and Philosophy* was spread out to computer science.

1986

The top three journals *Language, Linguistics,* and *Linguistics Inquiry* remained the same as in 1982. There were three philosophy journals, *Philosophical Review, Mind,* and *Semiotica*, five psychology journals, *Cognition, Journal of Memory and Language, Psychological Review, Cognitive Psychology,* and *Memory & Cognition* that were influential linguistics. *Journal of Linguistics* had an influence on anthropology, and the influence of *Linguistics and Philosophy* was spread out to philosophy. The influences of *Linguistics Inquiry* and *Language* were distributed to anthropology and psychology; in addition, *Language* had an influence on philosophy.

1990

Language was the most influential journal in linguistics as in the previous time periods, followed by *Cognition* from psychology, *Linguistics Inquiry, Journal of Memory and Language* from psychology, and *Linguistics*. There were six more psychology journals, *Psychological Review, Cognitive Psychology, Memory & Language, Journal of Experimental Psychology - General, Cognitive Science*, and *JMB*, one neuroscience journal, *Behavioral and Brain Sciences* and one philosophy journal, *Mind*, that were included as influential journals.

The journals *Linguistics* and *Linguistics and Philosophy* had an influence on philosophy, and the influences of *Journal of Linguistics*, *Linguistics Inquiry*, and *Journal of Psycholinguistic Research* were spread to Anthropology. *Language* had influence on anthropology and philosophy.

1994

The most influential journal was *Language*, followed by *Linguistics Inquiry* and *Linguistics*. Others include seven psychology journals, *Cognition, Journal of Memory and Language, Cognitive Psychology, Psychological Review, Memory & Language, Cognitive Science*, one philosophy journal, *Mind*, one computer science journal, *Communications of the ACM*, and one neuroscience journal, *Brain*. The journals *Linguistics and Philosophy* and *Language and Cognitive Processes* had an influence on philosophy, and the influences of *Journal of Linguistics, Language and Cognitive Processes* were spread to Anthropology. *Language* had an influence on anthropology and philosophy, and the influence of *Journal of Child Language* was spread to psychology.

Summary

Language was the most influential journal throughout the time periods, showing influences on other disciplines, anthropology and philosophy. *Journal of*

Linguistics had an influence on anthropology consistently. Journals mostly from psychology were very influential on linguistics. Neuroscience journals, *Brain* and *Behavioral and Brain Sciences* and philosophy journal *Mind* were also influential on linguistics.

Philosophy

1982

The most influential journal in Philosophy was *Philosophical Review*, followed by *Language* from linguistics, *Mind, Philosophical Studies, Nous, Monist, Analysis, Journal of Philosophical Logic, Philosophy and Phenomenological Research*, and *Philosophia*. Other journals included one anthropology journal *Man* and one psychology journal *Cognitive Science*. The journals *Mind* and *Philosophical Review* had an influence on linguistics.

1986

The most influential journal was *Mind*, followed by *Philosophical Review*. *Language* from linguistics was the third most influential journals, and seven other philosophical journals *Nous, Philosophical Studies, Analysis, Monist, Philosophy and Phenomenological Research, Philosophia,* and *Journal of Philosophical Logic* were included. Others include two more linguistics journals *Linguistics* and *Linguistics and Philosophy*, one anthropology journal *Man*, and two neuroscience journals, *BRN* and *Behavioral and Brain Sciences*. The influences of *Mind, Philosophical Review*, and *Semiotica* were distributed to linguistics.

1990

Mind and *Philosophical Review* remained at the top as in 1986, followed by *Language*. The rest of the influential philosophy journals *Philosophical Studies,* *Nous, Analysis, Monist, Philosophy and Phenomenological Research, Philosophia,* and *Journal of Philosophical Logic*. Others included two neuroscience journals *Brain* and *Behavioral and Brain Sciences*, one anthropology journal *Man*, two more linguistics journals *Linguistics and Philosophy* and *Linguistics* and one psychology journal *Cognition*. The journals *Mind, Philosophical Review,* and *Monist* had influence on linguistics; additionally, the influences of *Philosophical Review* and *Monist* were spread out to anthropology. The journal *Semiotica* was not influential on philosophy, but its influence was distributed to anthropology and linguistics.

<u>1994</u>

Language was the most influential on philosophy journals, followed by *Mind, Philosophical Review, Philosophia, Nous, Analysis,* and *Philosophy and Phenomenological Research*. In addition, two more philosophy journals *Monist* and *PPL*, two neuroscience journals *Brain* and *Behavioral and Brain Sciences*, one more linguistics journal *Linguistics and Philosophy*, and two psychology journals *Cognition* and *Cognitive Psychology* were included as influential on philosophy. *Mind* was influential on anthropology and linguistics.

<u>Summary</u>

While *Mind* and *Philosophical Review* were influential throughout the time period, the linguistics journal *Language* was very influential on philosophy. *Linguistics and Philosophy* also was an influential source on philosophy. Philosophy journals, *Semiotica, Mind* and *Philosophical Review* were influential on linguistics and anthropology.

Psychology

1982

The most influential journal in psychology was *Psychological Review*, followed by *Cognitive Psychology*, *Journal of Memory and Language*, *Memory & Cognition*, *ACTA Psychologica*, *Cognition*, *Journal of Experimental Psychology - Human Perception and Performance*, *Journal of Experimental Psychology - General*, and *Artificial Intelligence* from computer science. *Artificial Intelligence* was more influential on psychology than on computer science. Among the influential journals in psychology, the influence of *ACTA Psychologica*, *Journal of Experimental Psychology - General*, and *Journal of Experimental Psychology - Human Perception and Performance* were distributed to neuroscience. While the influence of *Cognition* was spread out to anthropology, linguistics, and philosophy, that of *Cognitive Psychology* to neuroscience, computer science, anthropology, and linguistics. *Memory & Cognition* and *Journal of Memory and Language* were influential on anthropology and linguistics. The influence of *Psychological Review* was spread out to neuroscience, computer science, anthropology, and linguistics.

1986

The top four journals *Psychological Review*, *Cognitive Psychology*, *Journal of Memory and Language*, and *Memory and Cognition*, remained the same as in 1982. There were five more psychology journals *Cognition*, *Cognitive Science*, *ACTA Psychologica*, *Journal of Experimental Psychology - Human Perception and Performance*, and *Journal of Experimental Psychology - General*, three linguistics journals *Language*, *Linguistics Inquiry*, and *Journal of Child Language*, and four neuroscience journals *Neuropsychologia*, *Behavioral and Brain Sciences*, *Cortex*, and *Brain*, that were included as influential on psychology.

While the influence of *ACTA Psychologica, Journal of Experimental Psychology - Human Perception and Performance*, and *Journal of Experimental Psychology - General* remained as influential journals on neuroscience, that of *Cognition* moved from philosophy in 1982 to neuroscience, in addition to anthropology and linguistics. The influence of *Cognitive Psychology* was spread out across the other disciplines, and that of *Memory & Language, Journal of Memory and Language*, and *Psychological Review* was spread out to the other disciplines except to philosophy. *Cognitive Science* became influential on psychology as well as computer science and anthropology in this time period.

1990

The top seven journals in psychology were *Psychological Review*, followed by *Cognitive Psychology, Memory & Cognition, Journal of Memory and Language, Cognition, Journal of Experimental Psychology - General*, and *Journal of Experimental Psychology - Human Perception and Performance*. Others include four neuroscience journals *Behavioral and Brain Sciences, Neuropsychologia, Cortex,* and *Brain,* two more psychology journals *Cognitive Science, ACTA Psychologica* and one computer science journal *Artificial Intelligence*. There were six linguistics journals marginally influential on psychology. The influences of *Cognition* and *Psychological Review* were spread out to all the other disciplines, and those of *Cognitive Psychology, Memory & Cognition, Journal of Memory and Language*, and *Journal of Experimental Psychology - General* were to the other disciplines except philosophy. *Cognitive Science* had an influence on all the other disciplines except neuroscience, and *Journal of Experimental Psychology - General* had an influence on neuroscience, computer science, and anthropology.

1994

The top two journals, *Psychological Review* and *Cognitive Psychology*, remained the same as in 1990. The other influential psychology journals include *Cognition, Memory & Cognition, Journal of Memory and Language, Journal of Experimental Psychology - General,* and *Journal of Experimental Psychology - Human Perception and Performance, Cognitive Science, ACTA Psychologica,* and *Cognitive Development*. Others include six neuroscience journals *Behavioral and Brain Sciences, Neuropsychologia, Cortex, Brain, Brain and Cognition,* and *Journal of Neuroscience*, one linguistics journal *Journal of Child Language*, one computer science journal *Artificial Intelligence*.

The influences of *Cognition* and *Cognitive Psychology* were distributed to all the other disciplines, showing their interdisciplinary dimensions. While *Memory & Cognition, Journal of Memory and Language*, and *Psychological Review* had an influence on neuroscience, anthropology, and linguistics, *Psychological Review* added its influence to computer science as well. The journals *ACTA Pscyhologica, Cognitive Neuropsychology, Journal of Experimental Psychology - Human Perception and Performance, Journal of Experimental Psychology - General* had influence on neuroscience; additionally, *Cognitive Neuropsychology* had an influence on linguistics and *Journal of Experimental Psychology - General* had on anthropology. For the first time, *Cognitive Development* appeared as influential on psychology as well as a marginal influence on linguistics.

Summary

Overall, the influences of *Cognition, Cognitive Psychology*, and *Psychological Review* appear to be broadly based across all the disciplines. Consistently throughout the time periods, *Cognitive Science* and *Psychological Review* had an influence on computer science journals.

5.3. JOURNAL STATUS IN NETWORK

Can the status of each journal in the journal citation network be measured in terms of its relative importance in cognitive science?

Methods

To measure the journals' status in the network, the data set for 1994 was used. From 85 journals included in the network for 1994, 81 journals were selected due to some missing data for the total number of references each journal makes per year. A matrix language, the SAS/IML (Interactive Matrix Language) software was used to compute the measures, based on the models and examples (Kim, 1992) for the importance index (Salancik, 1986), the measure of standing (Doreian, 1985, 1988), and the influence weight (Narin, Pinski, and Gee, 1976), which were explained in Chapter II. Using the three journal citation measures, the journals in the network were ranked to compare their status in the network. The entire journal is listed by the order of the journal ranks by the importance index in Appendix III, containing the importance index, the ranks by the measure of standing, the measures of standing, the ranks by the influence weight, the influence weight, and the discipline in which each journal is classified.

In this study, the journal ranks based on the three measures are compared.

Results

The Spearman rank correlation coefficient indicated that the journal ranks among the measures were strongly related to each other. The correlation coefficient of importance index with the measure of standing and the influence weight were .88 ($p < .001$) and .82 ($p < .001$) respectively, whereas the one between the measure of standing and the influence weight was .76 ($p < .001$). Despite the strong correlation among the journal ranks, there were disagreements in relative ranks of the pairs of the journals among difference measures, not corresponding very closely by the regression lines as shown in Figure 5.3.1. There was more consistency in the ranking of journals between the measure of standing and the importance index than there was between the influence weight and the other measures.

The importance index can be ranged from 1 to an unspecified high index, whereas the averages of the standing measure and the influence weight are normalized to 1. The mean of the importance index was 1.074 and twenty-seven journals were above the mean; eight psychology journals *(Psychological Review, Cognition, Cognitive Psychology, Journal of Memory and Language, Cognitive Science, Memory & Language, Journal of Experimental Psychology - General, Journal of Experimental Psychology - Human Perception and Performance*), six computer science journals (*Artificial Intelligence, Communications of the ACM, Biological Cybernetics, Machine Learning, IEEE Transactions on Pattern Analysis and Machine Intelligence, Neural Networks*), five philosophy journals (*Mind, Philosophical Review, Philosophical Studies, Nous, Analysis*), five neuroscience journals (*Behavioral and Brain Sciences, Brain, Neuropsychologia, Journal of Neuroscience, Journal of Neurophysiology*), and three linguistics journals (*Language, Linguistics Inquiry, Linguistics*).

The measure of standing included twenty-four journals above the mean; eleven neuroscience journals (*Journal of Neuroscience, Trends in Neurosciences, Journal of Neurophysiology, Neuroscience, Neuropsychologia, Annual Review of Neuroscience, Brain, Behavioral and Brain Sciences, Cortex, Journal of Cognitive Neuroscience, Brain and Cognition*), ten psychology journals (*Psychological Review, Journal of Experimental Psychology - Human Perception and Performance, Cognitive Psychology, Cognition, Journal of Memory and Language, Memory & Language, Journal of Experimental Psychology - General , Cognitive Science, ACTA Psychologica, Cognitive Neuropsychology*), two computer science journals (*Biological Cybernetics, Artificial Intelligence*), and one linguistics journals (*Language*).

Using the influence weight, twenty-three journals were above the mean; eight psychology journals (*Cognitive Science, Psychological Review, Journal of Experimental Psychology - General, Cognitive Science, Journal of Memory and Language, ACTA Psychologica, Memory & Language, Cognition*), five linguistics *journals (Language, Linguistics Inquiry, Linguistics and Philosophy, Linguistics, Journal of LInguistics*), four philosophy journals (*Mind, Philosophical Review, Journal of Philosophical Logic, Nous*), three computer science journals (*AI Magazine, Artificial Intelligence, Communications of the ACM*), and three neuroscience journals (*Annual Review of Neuroscience, Trends in Neurosciences, Brain*).

Table 5.3.1 shows the top thirty journals based on each of the measures. Among them, there were sixteen journals in common as listed in Table 5.3.2. Based on the measure of standing, neuroscience journals ranked particularly high, along with psychology journals. The measure of standing is interpreted as the weighted number of citations for both the citations received by other journals and the references made to other journals. A journal's prior status with other journals in the network acts as an exogenous factor and allows the status to vary across the journals. Therefore, if a journal interacts with fewer journals in the network, it has a lower status in the network that further reduces its status. The importance index of a journal is based on the weighted sum of other journals' dependencies on that journal. Consequently, as the dependency of important journals on a journal is higher, that journal's status in the network is elevated. Since the importance index is adjusted by the total references a journal makes per year, not restricted to the network journals, the index values tend to be low, close to 1.

The influence weight measures the interaction of the journal as the weighted number of citations received from the other journals over the total reference made

Table 5.3.1. The Top 30 Journals Based on Three Journal Citation Measures

Ranks	Importance Index	Measure of Standing	Influence Weight
1	Language	Journal of Neuroscience	Mind
2	Psychological Review	Trends In Neurosciences	Annual Review of Neuroscience
3	Cognition	Journal of Neurophysiology	Language
4	Mind	Psychological Review	Cognitive Psychology
5	Cognitive Psychology	Neuroscience	Psychological Review
6	Artificial Intelligence	Neuropsychologia	Linguistic Inquiry
7	Journal of Memory and Language	Annual Review of Neuroscience	Philosophical Review
8	Behavioral and Brain Sciences	Brain	Journal of Experimental Psychology-General
9	Cognitive Science	Journal of Experimental Psychology-Human Perception and Performance	Cognitive Science
10	Memory & Cognition	Cognitive Psychology	Artificial Intelligence Magazine
11	Brain	Cognition	Journal of Memory and Language
12	Philosophical Review	Journal of Memory and Language	Linguistics and Philosophy
13	Neuropsychologia	Memory & Cognition	Linguistics
14	Journal of Neuroscience	Journal of Experimental Psychology-General	Trends in Neurosciences
15	Journal of Experimental Psychology-General	Behavioral and Brain Sciences	ACTA Psychologica
16	Linguistic Inquiry	Cortex	Journal of Phonetics
17	Linguistics	Language	Brain
18	Journal of Experimental Psychology-Human Perception and Performance	Biological Cybernetics	Journal of Philosophical Logic
19	Philosophical Studies	Cognitive Science	Artificial Intelligence
20	Communications of The ACM	Journal of Cognitive Neuroscience	Memory & Cognition
21	Biological Cybernetics	Brain and Cognition	Communications of The ACM
22	Machine Learning	ACTA Psychologica	Cognition
23	Journal of Neurophysiology	Cognitive Neuropsychology	Nous
24	Nous	Artificial Intelligence	Analysis
25	IEEE Transactions on Pattern Analysis and Machine Intelligence	Neural Computation	Cognitive Development
26	Neural Networks	Neural Networks	Journal of Experimental Psychology-Human Perception and performance
27	Analysis	Linguistic Inquiry	Journal of Child Language
28	Trends In Neurosciences	Linguistics	Machine Learning
29	Cortex	Artificial Intelligence Magazine	Journal of Linguistics
30	Linguistics and Philosophy	Mind	Neuropsychologia

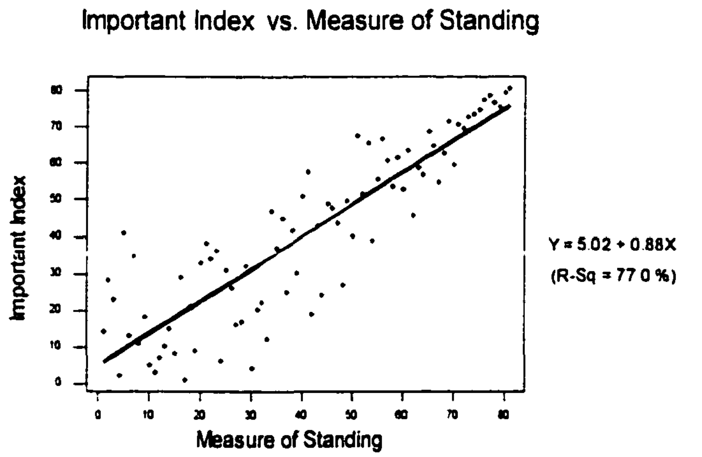
to the other journals in the network. If a journal receives more references than it gives out to the other journals, the input-output ratio of the journal is high to be influential in the network. Thus, a journal does not have to be interactive with other journals in the network to be ranked as influential.

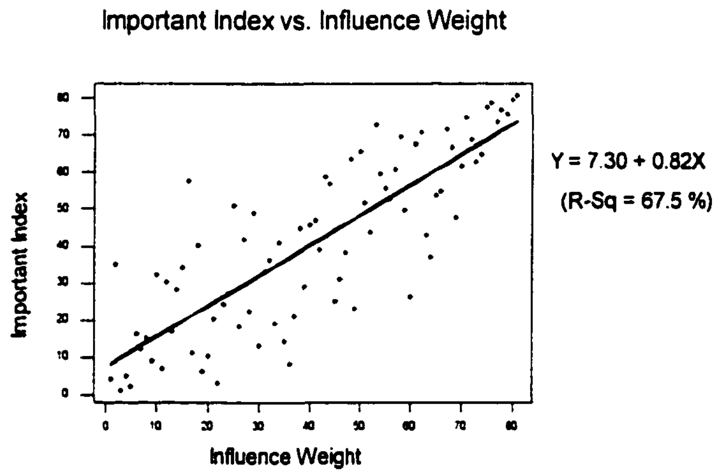
Table 5.3.2. Sixteen Common Journals out of the Top 30 Journals

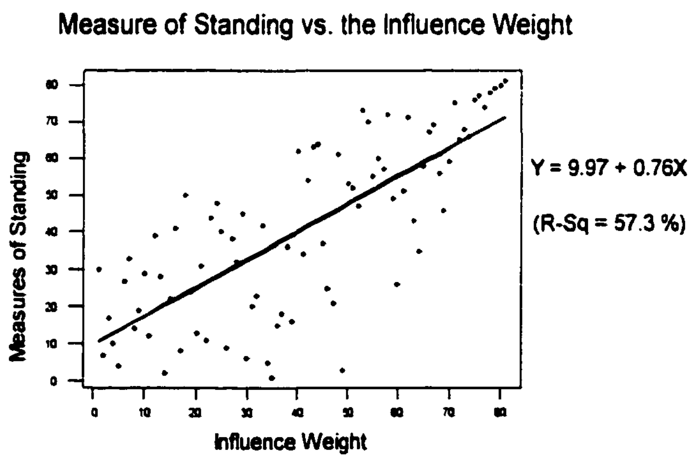
Journal	Discipline
Artificial Intelligence	CS
Brain	NS
Cognition	PSY
Cognitive Psychology	PSY
Cognitive Science	PSY
Journal of Experimental Psychology-General	PSY
Journal of Experimental Psychology-Human Perception and Performance	PSY
Journal of Memory and Language	PSY
Language	LING
Linguistic Inquiry	LING
Linguistics	LING
Memory & Cognition	PSY
Mind	PHIL
Neuropsychologia	NS
Psychological Review	PSY
Trends In Neurosciences	NS

Overall, the difference of the journals' ranking among the different measures results may come from different approaches to applying the general input-output model. The journal network created for this study was not limited to one discipline or sub-discipline, and measuring the journal's influence on the network has to be examined with caution. The journals tend to cite journals in their own discipline and hardly cite journals in the other discipline. As described in the first section of this chapter, the linkages of the network were not high as a consequence. Neuroscience journals tend to have a higher citation rate among their own journals than other disciplines, which might have contributed to a higher standing. It appeared that the importance index provided more stable measure in this journal citation network by setting an exogenous factor as 1, rather than having the exogenous factor as a journal's prior status in the network which allows the status to vary across journals.

Figure 5.3.1. Regression Plots of the Journal Ranks







5.4. CO-CITATIONS AND INTERNAL STRUCTURE

Can co-citation analysis of journals shed light on the internal structure of cognitive science itself?

A method for examining citation patterns among journals in cognitive science is to use journal co-citation data. Journal co-citation occurs when articles from two journals are jointly cited by other publications. That is, they are cited in the same list of references in later research works. The raw data consist of the number of citing articles in which these joint citations occur. From the raw data, proximity of journals is measured as similarity using Pearson's product-moment correlation coefficients for use in multivariate analysis.

In this study, the purpose of using co-citation data is to classify journals into a number of groups to provide insights into the organization of the journals selected in cognitive science. The results are compared with the structure of the inter-citation journal network examined in the previous section. Two data reduction techniques of multivariate analysis, cluster analysis and a multidimensional scaling method are used. Using cluster analysis, the journals are grouped together in such a way that journals residing in a particular group are more similar to each other than to journals belonging to other groups. Multidimensional scaling provides a display of the co-citation linkages of the journals in two-dimensional space to identify some dimensions underlying their placement.

Methods

A symmetric matrix that consisted of the raw frequency data had a null value for the diagonal cells, because counting co-citation frequency between the same journal was problematic. Adopting the methods often used in other research (McCain, 1990), however, the diagonal cells of the matrix were adjusted as the maximum number co-cited with other journals for each journal. Then, the matrix was converted as a similarity matrix using Pearson's product-moment correlation coefficient.

The data collected for co-citation analysis is limited to 1996. Although it is not exactly comparable with a set of the inter-citation journal networks, it could give insights into how the structure of cognitive science is portrayed using a different kind of citation data. While the inter-citation structure of the network can be a measure of interactivity between journals, the co-citation relationships reflect perceived similarities in their contents, relative prominence and utility recognized by other publications.

Two data reduction techniques of multivariate analysis, cluster analysis and multidimensional scaling, are used. Using cluster analysis, the journals are grouped such that journals residing in a particular group are more similar to each other than to journals belonging to other groups. Multidimensional scaling provides a display of the co-citation linkages of 76 journals in two-dimensional space to identify some dimensions underlying their placement.

An agglomerative hierarchical method of cluster analysis is used, which begins with all journals being separate, each forming its own cluster. In the first level, the two journals close together are joined. In the next level, either a third journal joins the first two, or two other journals join together into a different cluster. This process continues until all clusters are joined into one. To determine how the distance between two clusters is defined, the average linkage method is used. In average linkage, the distance between two clusters is defined as the average distance between an observation in one cluster and an observation in the other cluster. Cluster analysis provides a dendrogram, a tree structure, illustrating the partitions that have been effected at each successive level. Minitab for Window (release 12.2), was used to run the clustering procedure and produce the dendrogram shown in Figure 5.4.1.

Multidimensional scaling is a data reduction technique that uses proximities between objects to produce a spatial representation of the objects. The derived spatial representation consists of a geometric configuration of points on a map, each point corresponding to one of the objects. A co-citation map using this technique is provided to determine the underlying dimensions that contribute to the perceived relationships among the journals. The SAS system for Windows (release 6.12) was used to run a multidimensional scaling procedure.

Results

The Co-citation Clusters

Journals with similar co-citation patterns are identified and displayed in a dendrogram as shown in Figure 5.4.1. In the dendrogram, the abbreviations of journals were used. The list of journals with abbreviations is provided in Appendix I. The level of similarity for a journal being grouped in a cluster is indicated on the vertical axis. Once a journal is grouped in a cluster based on its degree of similarity, it is not reassigned to other groups, nor is it possible to display overlapping relationships.

The co-citation clusters presented in a dendrogram shown in the Figure 5.4.1 may be identified as five major groupings at about the 47 % similarity level. The first grouping on the left of the dendrogram represents the computer science group, which is composed of two subject-specialized co-citation clusters: neural networks and artificial intelligence. *Computational Linguistics*, categorized as linguistics in the inter-citation journal network, was included in the artificial intelligence group.

The second grouping located in the middle represents anthropology. Although the *Journal of Social and Evolutionary Systems* and *Man* were eventually joined with the anthropology cluster later, their similarity levels to the rest of the

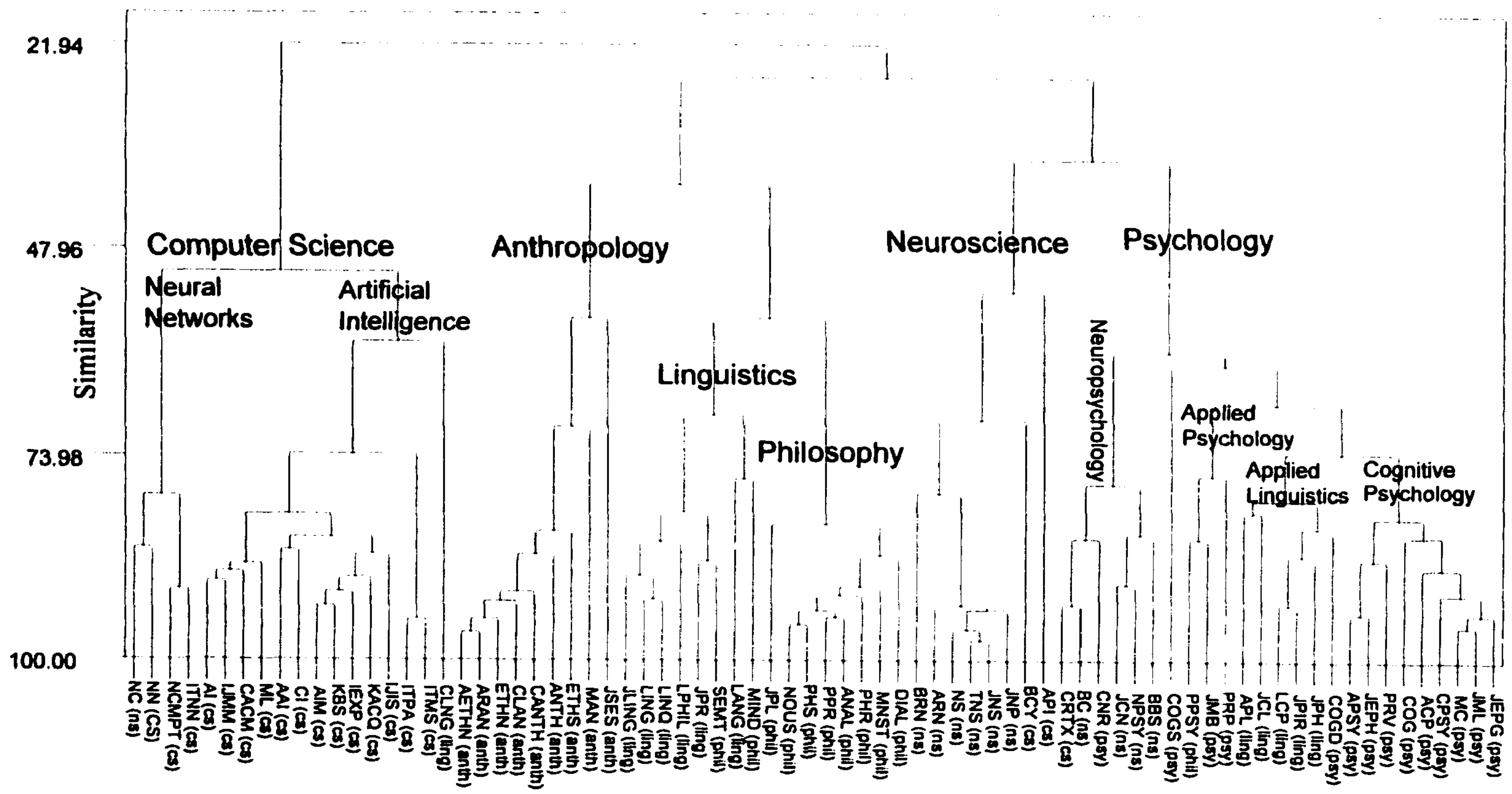


Figure 5.4.1. Co-Citation Clusters (1996)

* Journal abbreviations are explained in Appendix I.

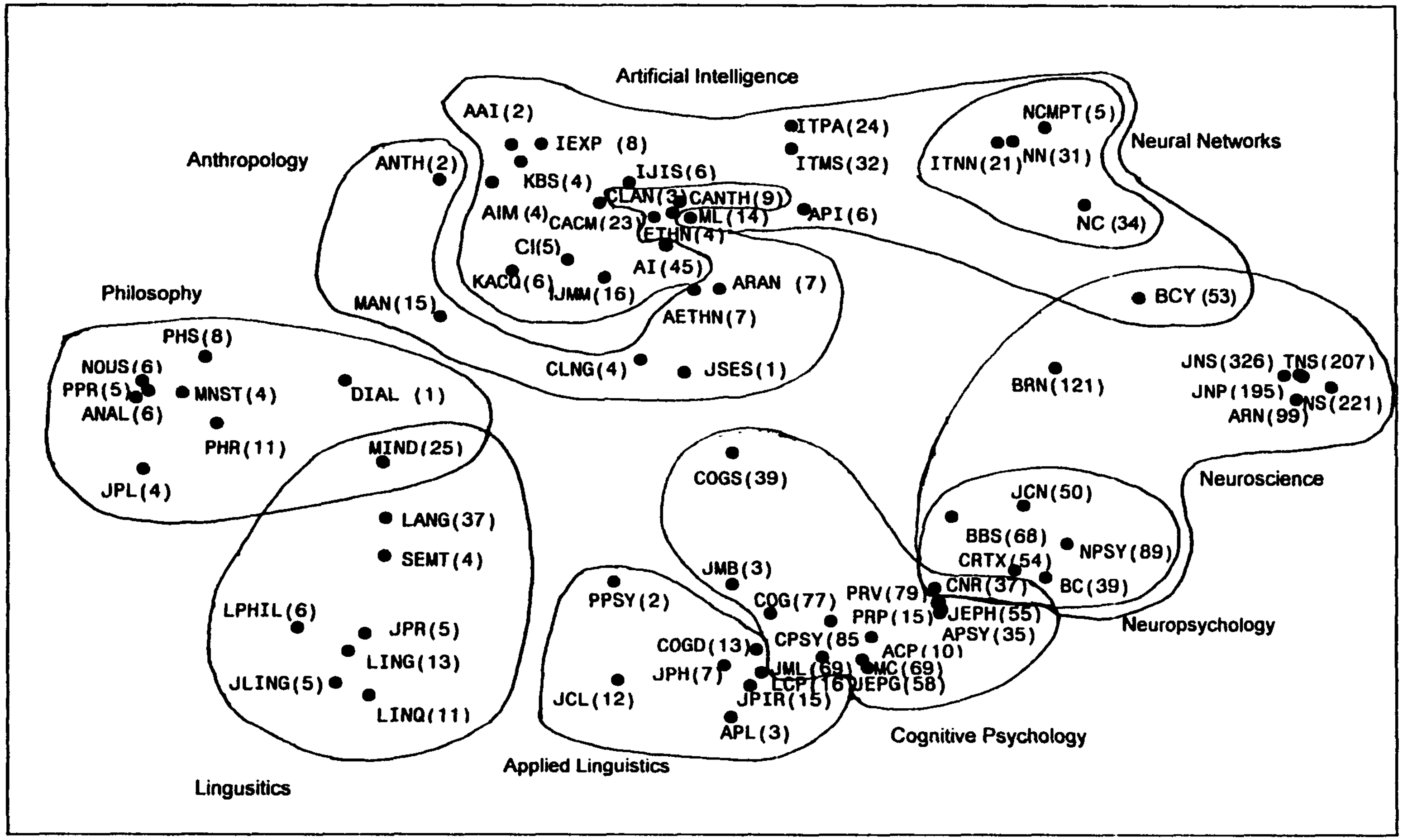


Figure 5.4.2. Co-citation Map (1996)

anthropology journals were somewhat lower. The third grouping is split in two separate clusters: linguistics and philosophy. The linguistics cluster was composed of general linguistics journals and two philosophy journals, *Semiotica* and *Mind.* In the philosophy cluster, the rest of the philosophy journals, except *Philosophical Psychology,* were included.

The fourth grouping represents the neuroscience group comprised mainly of general neuroscience journals, including *Biological Cybernetics* and *Applied Intelligence* that were pre-determined as computer science journals based on the LC classification number.

The fifth cluster may be identified as general psychology with its components being very diverse. It is largely composed of two specialized co-citation clusters: neuropsychology and applied/cognitive psychology. The neuropsychology cluster is composed of journals from neuroscience, specializing in clinical neuropsychology, including *Cognitive Neuropsychology* from psychology. In the applied/cognitive psychology cluster, *Cognitive Science* formed its own cluster separate from the rest. The applied psychology cluster includes the journals from philosophy, *Philosophical Psychology,* and two psychology journals, *Journal of Mind and Behavior* and *Psychology Reports.* The cognitive psychology cluster is composed of two specialized clusters: applied linguistics and cognitive/general psychology. The applied linguistics cluster is comprised of *Applied Psycholinguistics*, *Journal of Child Language*, *Journal of Phonetics*, *Language and Cognitive Processes*, *Journal of Psycholinguistics Research*, and *Journal of Psycholinguistic Research.* The cognitive/general psychology cluster is composed of the rest of the psychology journals.

Co-citation Map

A two-dimensional map of 76 journals based on the same similarity matrix of co-citation between journals is shown in Figure 5.4.2. Multidimensional scaling positions points representing the journals in two-dimensional space, in such a way that their relative positions in the space reflect the degree of perceived similarity between the journals. The cluster boundaries at two levels are drawn on the map by the disciplines and the co-citation clusters. The mean co-citation rate for each journal is added to the map, indicating the relative importance or utility of journals within a cluster.

The map identifies journal groups in the journal network. The groups delineated by the co-citation cluster and predetermined by the disciplines are identified.

In the computer science cluster, *Biological Cybernetics* is in a close cross-boundary position with both the neural network subgroup and the neuroscience cluster. *Applied Intelligence* which is grouped to neuroscience in the co-citation cluster (dendrogram) is positioned closer with computer science on the map. *Computational Linguistics* is near the computer science journals and grouped with them, far from the linguistics cluster, as shown in the dendrogram of Figure 5.4.1. The neural networks journals are positioned close to the neuroscience cluster and the journals in pattern recognition and cybernetics of computer science. Overall, *Artificial Intelligence* is centered in computer science with the highest co-citation mean. The anthropology cluster, which is located close to computer science, is not identifiable by the co-citation clusters. The journal *Man* has the highest mean co-citation rate with the anthropology cluster.

The neuroscience cluster lies near the neural networks subgroup and the neuropsychology subgroup. *Brain* was far from the rest of the neuroscience journals. *Cognitive Science* in psychology is located at the center of the map, indicating it has a high degree of similarity with many other journals. It is grouped with the psychology, though it was farther from the rest of the psychology journals. *Philosophical psychology* is near the psychology cluster, rather than the philosophy cluster. Journals clustered as neuropsychology are located near both psychology and neuroscience clusters. *Journal of Neuropsychology* lies near the cross-boundary between psychology and neuropsychology clusters. Journals clustered as applied linguistics are grouped closer to the psychology cluster rather than the linguistics cluster.

The linguistics cluster lies close to the philosophy cluster, with *Semiotica* located near the linguistics journals. *Language* and *Mind* were clustered very closely together. While the relative importance of *Language* is the highest within the linguistics cluster, that of *Mind* is the highest within the philosophy cluster which reveals a strong relationship between the linguistics and philosophy clusters. In contrast, the linguistics journals, which are classified in the applied psychology cluster in the dendrogram, are very closely mapped with psychology journals. The philosophical journal *Philosophical* Psychology is closely mapped with the psychology cluster.

The journals, which are classified in the neuropsychology cluster, are close to the psychology cluster, rather than to the neuroscience cluster. Among psychology journals, *Psychological Review* has the highest mean co-citation rate within the psychology cluster.

Discussion

The citation clusters and maps display journals based on similarity of joint use patterns that reflect the citing choices made by the researchers publishing their articles in the journals. With these methods, visualizing the relationships of the journals that have been chosen by researchers.

The journal clusters created in the network are similar to how the journals were assigned to each discipline, although there are some differences for the journals whose subject categories are involved in more than one discipline. While the journals selected in the network were divided by the Library of Congress classification number, clustering of journals by co-citation, as an indicator of use, may represent an indirect means of determining a partial structure for a given knowledge domain.

While the hierarchical cluster analysis provides groupings of the journals based on their similarity, the co-citation map displays a broad subject relationship and relative similarity among the journals in the network. A comparison of the disciplines predetermined by the LC number shows that, there are some differences in now journals are classified into clusters. For example, some cross-boundary journals are clearly shown in the co-citation clusters and maps. Furthermore, the mean co-citation rate quantifies the relative importance of journals within a cluster on the map.

The structure of co-citation clusters and mapping is comparable to the results from the analysis of individual journal impacts in the previous section, which is based on journal inter-citation transaction. Most of the journals identified as influential in the journal impact analysis are also identified as influential using mean co-citation rates within their clusters. In anthropology, the interaction with other disciplines and relative importance of *Man* are recognized. *Psychological Review* in psychology distributes its influence to other disciplines and its relative importance was perceived by researchers. *Artificial Intelligence* was recognized as an influential journal in computer science and its importance in computer science is perceived by researchers. In philosophy, *Mind* is influential journal and its importance was recognized by researchers. *Language* is the most influential journal and its importance in linguistics are recognized in the co-citation map. The results from co-citation analysis and inter-citation analysis of journals reveal a strong interaction between linguistics and philosophy. In the neuroscience journals, since the co-citation clusters are divided into two groups, general neuroscience and neuropsychology clusters, the results from co-citation and inter-citation analysis are not nearly as convincing as in other disciplines.

The differences between inter-citations and co-citations of journals are apparent both at the conceptual level and at the organization level of data. Conceptually, while inter-citations of journals are citing and being cited activities, the co-citations of journals reflect perceived similarities in their contents that are recognized by other researchers. In terms of the data organization, inter-citations are represented as asymmetrical relations between journals by making references to other journals and receiving citations by other journals. Co-citations on the other hand are represented as symmetrical relations between two journals when they are cited by a third publication. Co-citation mapping displays a clear structure of the journals and the discipline clusters in the network.

5.5. SUMMARY AND DISCUSSION

The macro-analysis of this chapter has sought to represent the broad structural patterns of research interactivity in cognitive science in the four one-year time periods of 1982, 1986, 1990, and 1994. The previous chapter employed a large sample of specific citation data from the journal *Cognitive Science*. In contrast, this chapter's analysis uses an input-output transaction matrix of citing and cited journal samples from the six constituent disciplines and a co-citation matrix of the journal samples. The research questions in this chapter sought to examine: 1) a broad structural change in research interactions among the constituent disciplines of cognitive science; 2) the influence of each journal in the journal citation network; 3) the relative importance of each journal in the network; and 4) the internal structure of cognitive science via co-citation analysis. To investigate broad structural changes in research interactions among the constituent disciplines of cognitive science, the citation counts at the journal level were aggregated. Although the aggregation of the lower (journal) level of data into a higher (discipline) level may result in the sacrifice of some unique information about each journal, the analysis had to focus upon the aggregated citation choices of entire set of disciplines.

Among the constituent disciplines of cognitive science, psychology was the center for research interactivity throughout the four time periods of 1982, 1986, 1990, and 1994. Psychology was cited consistently by neuroscience, anthropology, computer science and linguistics during the four time periods. Although the interaction between psychology and philosophy was weak in 1982 and 1986, it became strong in 1994. The analysis indicated that psychology was consistently the most influential discipline. In 1982, psychology was very conservative in citing sources from the other disciplines. However, other disciplines tended to cite psychology heavily, giving psychology a "feeder" disciplinary status in cognitive science.

The citation patterns between neuroscience and computer science remain consistent, with neuroscience making frequent references to computer science journals, but receiving marginal citation status from computer science. The *citing* interactivity of neuroscience with computer science increased until 1990, while the *cited* interactivity decreased slightly over the time period. The analysis showed a weak citing interactivity of neuroscience with anthropology in 1982, but little significant activity occurred thereafter.

Philosophy had a strong interaction with linguistics throughout the time period, though its citing interactivity with linguistics with philosophy was initially very minimal in 1982. Anthropology showed a weak but consistent citing and cited interactivity with philosophy.

Linguistics had a strong interaction with psychology, as indicated before. It also influenced anthropology constantly. Anthropology tended to cite more from psychology and linguistics, but only marginally from philosophy. Throughout the four time periods, the interactivity of anthropology was the lowest in the network.

In summary, the interactions among the disciplines in 1982 were relative constrained and intra-disciplinary interactivity was prevalent (except for interactivity with psychology). The analysis showed considerable stability of the network, with very similar research interactivity among the disciplines. Thus, the disciplines appear to have bonded together in a rather stable way, baring the marginalization of anthropology.

The influence of each journal in the journal network is analyzed in the following section by discipline. Among the neuroscience journals, *Behavioral and Brain Sciences* and *Brain,* were interactive with other disciplines throughout the entire time period. *Brain* had an influence on linguistics, philosophy, and psychology, whereas *Behavioral and Brain Sciences* had an influence on anthropology, linguistics, philosophy, and psychology. *Psychological Review* influenced neuroscience journals rather heavily.

Among the computer science journals, *Artificial Intelligence* consistently influenced both on computer science and psychology throughout all the time periods. The influence of *Biological Cybernetics* on neuroscience increased over the time period. Journals in psychology, neuroscience, and linguistics were important sources for computer science.

The journals, *American Ethnologist*, *Current Anthropology*, *Man*, and *Annual Review of Anthropology*, as well as the *Journal of Memory and Language* from psychology, were influential journals in anthropology. Anthropology journals were influenced by journals from psychology, linguistics, philosophy, and neuroscience. However, anthropology's influence did not reach the other disciplines throughout the time periods, except for one journal, *Man,* which in turn influenced philosophy.

Language was the most influential journal in linguistics throughout all the time periods, and it rendered its influence to other disciplines, particularly anthropology and philosophy. The *Journal of Linguistics* influenced anthropology consistently. Psychology journals influenced linguistics considerably. The neuroscience journals, *Brain* and *Behavioral and Brain Sciences*, and philosophy journal *Mind*, also influenced on linguistics.

While *Mind* and *Philosophical Review* in philosophy were influential journals throughout the time period, the linguistics journal *Language* influenced philosophy heavily. *Linguistics and Philosophy* also influenced philosophy considerably. The philosophy journals, *Semiotica, Mind* and *Philosophical Review* influenced linguistics and anthropology to a considerable extent.

Among the psychology journals, the influence of *Cognition*, *Cognitive Psychology*, and *Psychological Review* appears to be broadly based across all the disciplines. *Cognitive Science* and *Psychological Review* influenced computer science journals consistently throughout the various time periods.

From the three different measures (journal status, importance index, measure of standing, and influence weight), there were 16 common journals that were ranked in the top 30 among 81 cognitive science journals. Hence, this journal list constitutes a kind of "core" set for cognitive science. The journals are listed below:

Artificial Intelligence (CS)
Brain (NS)
Cognition (PSY)
Cognitive Psychology (PSY)
Cognitive Science (PSY)
Journal of Experimental Psychology-General (PSY)
Journal of Experimental Psychology-Human Perception and Performance (PSY)
Journal of Memory and Language (PSY)
Language (LING)
Linguistic Inquiry (LING)
Linguistics (LING)
Memory & Cognition (PSY)
Mind (PHIL)
Neuropsychologia (NS)
Psychological Review (PSY)
Trends In Neurosciences (NS)

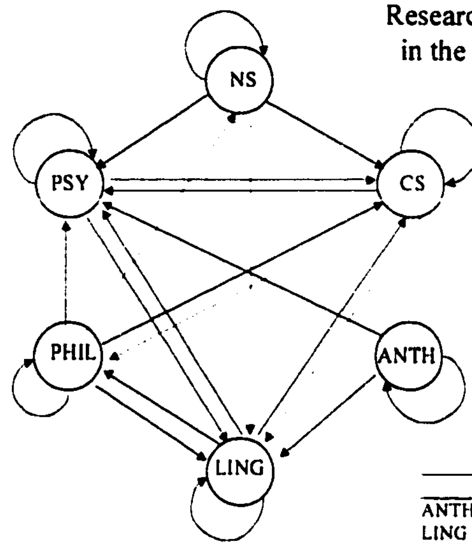
The citation clusters and maps in the previous chapter display the journals according to the similarity of their joint use patterns. The journal clusters created in the network are similar to the way the journals were assigned to each discipline, although there are some differences for the journals whose subject categories are involved in a more than one discipline. While the journals selected in the network were divided by the Library of Congress classification numbers, the clustering of journals by co-citation (as an indicator of use) may likewise represent an indirect means of determining the internal structure of cognitive science. Some cross-boundary journals were clearly shown in the co-citation clusters and maps. The co-citation map displays visually a broad subject relationship and relative similarity among the journals in the network. And the mean co-citation rate quantifies the relative importance of journals within each cluster.

As a result of the findings of the previous chapter, a graph representing research interactivity is compared with the overall research interactivity based on the journal inter-citation network. The disciplines of the articles published in *Cognitive Science* were regarded as citing disciplines, and the constituent disciplines cited in the articles were regarded as cited disciplines. Based on the measures of research interactivity used in this chapter, Figure 5.5.1 shows the research interactivity represented in the journal *Cognitive Science*. In Figure 5.5.2, the overall research interactivity, based on the four one-year time periods, is presented.

Since the citation patterns represented in the journal *Cognitive Science* are more microscopic than the structural patterns in the journal network (in terms of the content and time coverage and the focus of the journal), the interactivity among the disciplines is illustrated more vividly. Psychology was the center on the both graphs, while computer science was more interactive with other disciplines in *Cognitive Science* than it was in the journal network. In *Cognitive Science*, computer science was cited by all the constituent disciplines, except anthropology. Computer science also had a weak citing interactivity with philosophy and linguistics. Psychology in *Cognitive Science* had strong citing and cited interactivities with computer science, while it had only a cited interactivity with computer science. In contrast, while neuroscience had a strong citing and cited interactivity with psychology and computer science, neuroscience showed more interactions with philosophy and linguistics in *Cognitive Science*. That interactivity may indicate that neuroscience was more exposed to the network journals in computer science and psychology.

Figure 5.5.1. Research Interactivity Represented in *Cognitive Science*

Research Interactivity Represented in the Journal *Cognitive Science*

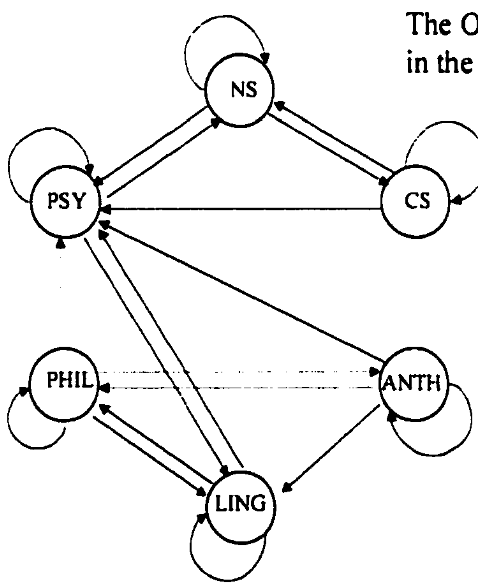


NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

	ANTH	LING	PHIL.	PSY	CS	NS
ANTH	1	1	0	1	0	0
LING	0	1	1	1	1	0
PHIL	0	1	1	1	1	•
PSY	0	1	0	1	1	1
CS	0	•	•	1	1	1
NS	0	•	0	1	1	1

Figure 5.5.2. Research Interactivity Represented in the Journal Inter-citation Network

The Overall Research Interactivity in the Journal Inter-citation Network



NS: Neuroscience
CS: Computer Science
ANTH: Anthropology
LING: Linguistics
PHIL: Philosophy
PSY: Psychology

	ANTH	LING	PHIL	PSY	CS	NS
ANTH	1	1	•	1	0	0
LING	0	1	1	1	0	0
PHIL	•	1	1	•	0	0
PSY	0	1	0	1	0	1
CS	0	0	0	1	1	1
NS	0	0	0	1	1	1

CHAPTER VI. SUMMARY AND CONCLUSIONS

This chapter summarizes the purpose, research questions, and results and findings of the study. It then discusses the implications and limitations of the study. Finally, it presents directions for future research and concludes with an overview.

6.1. OVERVIEW OF THE STUDY

The main purpose of this study was to analyze the overall research interactions among the contributing disciplines of cognitive science through citation analysis of its literature, in order to understand its interdisciplinary dimensions. Three approaches were used to perform the analysis.

First, the citation patterns of six constituent disciplines represented in the interdisciplinary journal *Cognitive Science* were analyzed for the time period of 1977-1996. Second, based on the journal inter-citation network, research interactivity among the constituent disciplines was analyzed along with measures of the importance of each journal, both within the discipline and in the entire network. A number of important journals in the journal inter-citation network of cognitive science was identified according to the different measures of journal status by their inter-citations. Third, clusters of journals based on co-citation similarity were formed, and a two-dimensional map that represented graphically the structure of cognitive science literature was generated.

6.2. SUMMARY OF STUDY FINDINGS

This section first summarizes findings related to citation patterns of the central journal *Cognitive Science*, and summarizes the findings on research interactivity of a cognitive science journal network.

Citation Patterns for the Journal *Cognitive Science*

Constituent Discipline Citation Rates

Citation rates in cognitive science have exhibited changes in terms of key constituent disciplines over time. As represented in references of the articles published in the journal *Cognitive Science*, the initial dominance of computer science gave way to psychology. Likewise, psychology commanded the largest number of citations in *Cognitive Science*, thus establishing its dominance as the key discipline in cognitive science, insofar as the journal *Cognitive Science* represents the area of cognitive science.

During the second period (1982-1986), linguistics apparently enriched itself as a discipline by drawing on cognitive science. Linguistics cited *Cognitive Science* heavily, and was cited heavily in *Cognitive Science*. However, linguistics decreased gradually its importance, both in terms of being cited *by Cognitive Science* and by citing *Cognitive Science* during in the third and fourth time periods (1987-1991 and 1992-1996). Nevertheless, it bounced back as a citing discipline of *Cognitive Science* in the fourth time period. Neuroscience appears to have drawn on cognitive science gradually, but only to minor extent.

Changes in Disciplinary Citation Rates

Among those disciplines cited in *Cognitive Science*, it was found that the citation rates for philosophy have decreased over time and the smaller number of philosophy articles published in *Cognitive Science* also contributed to the declining citation rates for philosophy. In contrast, the citation rates for psychology have increased over time and these increased citings also depended on the number of psychology articles published in *Cognitive Science*. The citation rates for computer science have decreased over time, with a corresponding apparent reduction in the number of computer science articles published in *Cognitive Science*. The citation rates for neuroscience have increased over time and the increase also depended on an increased number of neuroscience articles cited in *Cognitive Science*. The analysis of citations to anthropology and linguistics in *Cognitive Science* revealed no clear patterns, either through time or by the number of articles published for each in *Cognitive Science.* Overall, then, psychology and neuroscience showed a growth pattern as constituent disciplines, while computer science and philosophy showed a declining pattern as reference disciplines. Anthropology and Linguistics did not show any pattern either through time or by the number of articles cited in each discipline.

With respect to disciplines that cited *Cognitive Science* in their respective literatures, anthropology has increased in its number of citations up to 1988; afterwards it decreased in its number of citations. Likewise, philosophy increased to 1991, then decreased. Psychology, computer science, and neuroscience have continuously increased over time. Linguistics revealed no pattern.

Author Disciplinary Affiliation

The self-citation rates of authors from psychology, computer science, and linguistics were very high. But the disciplines that had a marginal appearance in *Cognitive Science* tended to cite psychology more than their own disciplines. Overall, the results indicate that the citation rates for the cited disciplines do depend on the disciplinary research areas of the authors who publish the articles in *Cognitive Science*. Moreover, the existing subject coverage or editorial policy of *Cognitive Science* can influence which disciplines are cited and how frequently they are cited.

Interdisciplinary Reach

The citation rates outside the discipline of each *Cognitive Science* article were not significantly different among the author groups. The analysis indicated the number of authors who collaborated did not make a significant difference in their tendency to cite reference materials. However, authors in *Cognitive Science* do tend to cite between two to seven different disciplines outside of their own areas, and their citation rates vary considerably. The number of authors who collaborate in research, whether they were from the same discipline or not, did not appear to be related outside disciplines cited. Therefore, there is a tendency for both individual or collaborating *Cognitive Science* article authors to cite multiple disciplines outside of their own areas of expertise, but to do so at widely different rates. Thus, interdisciplinarity has been alive and well through all time periods.

Impact of Author's Home Discipline

Cognitive Science authors from anthropology, philosophy, and neuroscience had the highest rates of interdisciplinary borrowing. In contrast, psychologists tend to draw on psychological research. Linguistics scholars and computer scientists also tend to look inwards. Possibly, the more internal literature a discipline has to draw upon, the less apparent need it has to go beyond its own boundaries for ideas, issues, and problem solutions. Additionally, certain disciplines can be relatively authoritative with respect to perplexing problems, such as the nature of mind or the function of cortical brain areas.

The articles published in *Cognitive Science* cited significantly more outside materials in the second time period (1982-1986) compared to the first time period, although they were not significantly different from the other two time periods, 1987-1991 and 1992-1996. There appears to be an increasing tendency to reach out to other disciplines to deal with the substantive or methodological issues attendant to cognitive science.

Research Interactivity in the Journal Citation Network

Research Interaction Among Disciplines

Among the disciplines included in the journal inter-citation network, psychology was the center for research interactivity throughout the four time periods, 1982, 1986, 1990, and 1994. The cited interactivity patterns for psychology were consistent with those of neuroscience, anthropology, computer science and linguistics for the four time periods. Interactivity between psychology and philosophy became strong in 1994, whereas interactivity had been weak in 1982 and 1986. The analysis indicates that psychology was consistently the most influential discipline. The tendency of psychology to cite linguistics was consistent with linguistics throughout the all time periods. Psychology tended to cite neuroscience heavily from the second period forward. In 1982, psychology was very conservative in citing sources from the other disciplines, although other disciplines tended to cite psychology heavily, giving psychology a feeder disciplinary status in cognitive science.

The citation patterns between neuroscience and computer science remain consistent, with neuroscience making frequent references to computer science journals, but receiving marginal citations from computer science. The *citing* interactivity of neuroscience with computer science increased until 1990, while the *cited* interactivity decreased slightly over the time period. The analysis showed a weak citing interactivity of neuroscience with anthropology in 1982, but little significant activity occurred thereafter.

Philosophy had a strong interaction with linguistics throughout the time period, although the analysis showed that the citing interactivity of linguistics with philosophy was initially very minimal in 1982. With anthropology, philosophy showed a weak citing and cited interactivity with philosophy.

Linguistics had a strong interaction with psychology, as indicated before. It also influenced anthropology constantly. Anthropology tended to cite more from psychology, and linguistics, but marginally from philosophy. Anthropology had a consistent, but weak interaction with philosophy in 1986 and 1994. Throughout the four time periods, the interactivity of anthropology was the lowest in the network.

In summary, although the interactions among the disciplines in 1982 were rather restricted (except those of psychology), the analysis showed considerable stability of the network, with a very similar mode of research interactivity among the disciplines. Thus, the disciplines appear to have bonded together in a rather stable way, with the exception of the marginalization of anthropology.

Individual Journal Impact

Neuroscience Journal Impact

Overall, the neuroscience journals, *Behavioral and Brain Sciences* and *Brain,* were interactive with other disciplines throughout the entire time period. *Brain* had an influence on linguistics, philosophy, and psychology, whereas *Behavioral and Brain* Sciences had an influence on anthropology, linguistics, philosophy, and psychology. Among the influential psychology journals that impacted neuroscience, *Psychological Review* was the most influential.

Computer Science Journal Impact

Throughout the time period, *Artificial Intelligence* had consistent influence not only on computer science, but also on psychology. The influence of *Biological Cybernetics* on neuroscience increased over the time period. Journals in psychology, neuroscience, and linguistics were important sources for computer science.

Anthropology Journal Impact

The journals, *American Ethnologist*, *Current Anthropology*, *Man*, and *Annual Review of Anthropology*, as well as the *Journal of Memory and Language* from psychology, were all influential journals in anthropology. The anthropology journals were influenced by journals from psychology, linguistics, philosophy, and neuroscience. However, anthropology's influence did not reach the other disciplines throughout the time periods, except for one journal, *Man*. In turn, *Man* influenced philosophy.

Linguistics Journal Impact

Language was the most influential journal in rendering its influence to other disciplines throughout the time periods, particularly anthropology and philosophy. The *Journal of Linguistics* influenced anthropology consistently. Journals mostly from psychology were very influential on linguistics. Neuroscience journals, *Brain* and *Behavioral and Brain Sciences*, and the philosophy journal *Mind*, were also influential on linguistics.

Philosophy Journal Impact

While *Mind* and *Philosophical Review* were influential throughout the time period, the linguistics journal *Language* was very influential on philosophy.

Linguistics and Philosophy also influenced philosophy considerably. The philosophy journals, *Semiotica, Mind* and *Philosophical Review* influenced linguistics and anthropology.

Psychology Journal Impact

Overall, the influence of *Cognition*, *Cognitive Psychology*, and *Psychological Review* appears to be broadly based across all the disciplines. Consistently throughout the time periods, *Cognitive Science* and *Psychological Review* influenced computer science journals.

Journal Status in Network

Three different measures (the importance index, the measure of standing, and the influence weight) were used. Overall, the differences in the journals' rankings between the different measures may have come from alternative approaches in applying the general input-output model. Because the journal network created for this study was not limited to one discipline or sub-discipline, assessing the influence of these measures on the network has to be examined with caution. Most journals in the network tended to cite journals in their own discipline and hardly ever cited journals in the other disciplines. As described in the first section of Chapter V, the linkages of the network were consequently not strong. Neuroscience journals tend to have a higher citation rate among their own class of journals than the other disciplines, which might have contributed to higher ranks in the neuroscience measure of standing. From a list of journals that were common among the three measures, sixteen journals ranked in the top 30 among 81 cognitive science journals. Hence, this journal list of 16 journals constitutes a kind of "core" set for cognitive science.

Artificial Intelligence (CS)
Brain (NS)
Cognition (PSY)
Cognitive Psychology (PSY)
Cognitive Science (PSY)
Journal of Experimental Psychology-General (PSY)
Journal of Experimental Psychology-Human Perception and Performance (PSY)
Journal of Memory and Language (PSY)
Language (LING)
Linguistic Inquiry (LING)
Linguistics (LING)
Memory & Cognition (PSY)
Mind (PHIL)
Neuropsychologia (NS)
Psychological Review (PSY)
Trends In Neurosciences (NS)

Co-citations and Internal Structure

The citation clusters and maps in the previous chapter display the journals according to the similarity of their joint use patterns. These joint use patterns reflect the citing choices made by the researchers who have published their articles in journals. Thus joint use patterns allow one to visualize the relationships of the journals to one another and reveal at least one representation of the internal structure of cognitive science.

The journal clusters created in the network are similar to the way the journals were assigned to each discipline, although there are some differences for the journals whose subject categories are involved in a more than one discipline. While the journals selected in the network were divided by the Library of Congress classification numbers, the clustering of journals by co-citation (as an indicator of use) may likewise represent an indirect means of determining the internal structure of cognitive science.

The hierarchical cluster analysis in Chapter V provided groupings of the journals based on their similarities. Compared with disciplines predetermined by the LC number, there were some notable differences in classifying the journals into clusters. Some cross-boundary journals were clearly shown in the co-citation clusters and maps. The co-citation map displays visually a broad set of subject relationships and relative similarities among the journals in the network. And the mean co-citation rate quantifies the relative importance of journals within a cluster.

6.3. LIMITATIONS OF THE STUDY

Because this study used citation data as an objective measure of scholarly quality, impact, scientific social structure, and as a measure of singular communication channels, it does not portray the substantive content of the field of cognitive science. The citation data herein only portrayed the recognition of the broad dimensions of the scientific field being studied according to its publications. Hence, the results of citation analysis should be used in conjunction with other qualitative and quantitative sources of information relevant to the scientific field being studied (Linsey, 1989).

Problems of data quality can arise in studies like the present one, which was drawn from the ISI on-line citation index databases, because data samples depend on data coverage in the citation index databases. There can also be a lot of variations in the journal names, particularly in cited journal names. Consequently, some journal counts can be missing, despite a thorough database search.

Since there is a lack of existing library classification systems for cognitive science, there was not a particular method available for classifying the cited reference into each constituent discipline and there might have some discrepancies in classification of sources. The Library of Congress classification numbers were used in this study, but the categories that these numbers represent can be rather broad, and not well suited to incorporating the unique attributes of cognitive science.

The selection and coverage of the journals in the journal network used in this research might have not been ideally representative of the field of cognitive science, even though these journals were selected carefully as a large set of representative samples. The journal status scores produced by the three different measures (importance, standing, and influence) resulted from only the interaction of journals within the network. Obviously, the list of important journals in cognitive science is determined largely by the selection of journals from which data are gathered to represent cognitive science.

Typically, a journal citation network is created within a discipline or a specific specialty area. In this study, however, the assumption that cognitive science is a broad scientific field drove the analysis. This research attempted to provide only a general picture of the interactions among the key journals. For the journal network, the data for the present study were limited to the aggregation of the four one-year time periods because of sampling constraints. Obviously a succession of two-year or three-year sampling periods for aggregation would provide a more exhaustive analysis.

Lastly, when journal selection is based on citing and cited journals in such a journal as *Cognitive Science*, the linkage indicators of a given journal with other journals can be incompletely expressed, or some linkages might be missing.

In conclusion, even though the citation analysis does not analyze the development of certain areas of research in terms of content, it does take a macro-level view of the area according to its written communication patterns, as indicated by an entire journal network. Macro-level views obviously sacrifice detail. Nevertheless, the use of such a macro-level view should serve to overcome the weaknesses of more restricted micro-level analyses.

6.4. IMPLICATIONS OF THE STUDY

The bibliometric study of research interactivity, especially the use of citation analysis, does reveal the nature and extent of interactions among different disciplinary fields contributing to cognitive science. This study has detected communication patterns and trends in cognitive science over time and has been based on various methods, using citation, inter-citation, and co-citation analyses.

Additionally, the identification of important journals in cognitive science should serve to support decision-making for collection development and management, whether such decision-making occurs among individual scholars or in traditional or digital library environments. The research based on inter-citation and co-citation analysis should also contribute to the development of classifications of knowledge to support interdisciplinary information retrieval.

Finally, such a study should provide a clearer picture of the dynamic structure of cognitive science over time.

6.5. FURTHER RESEARCH

The study provides some insight for future research directions. First, in addition to the journal *Cognitive Science*, other important journals listed in Chapter V could be good sources to use in investigating the interactions of the constituent disciplines of cognitive science.

Second, the selection of journals in the network can be limited to given sub-disciplines or specialty areas, so that close ties among journals should augment the in-depth research of a specific area.

Third, the constituent disciplines of cognitive science could well be expanded to the discipline of education. Education is now incorporated into the subtitle of *Cognitive Science*. In addition, since a number of academic programs in cognitive science and separate departments now exist in higher education, this recognized academic discipline can provide impetus for studying the field and its direction.

Finally, other research designs, which employ substantive content and qualitative analysis, or survey research, can shed additional light on the study of collaborative research in cognitive science and on the area's past or future development.

6.5. EPILOGUE

This study has attempted to provide a general picture of the key research interactions that have characterized the growth, interdisciplinary transactions and overall transformation of cognitive science from 1977 through 1996. The study's analysis first centered on bibliographic citation interactivity between the locus journal *Cognitive Science*, and the disciplinary cognates of psychology, computer science, linguistics, anthropology, and philosophy. Second, the analysis utilized a citation matrix that juxtaposed citing with cited journals in order to discern the degree to which the citation transactions have occurred throughout selected time periods. The broad picture of research interactivity that emerges indicates that cognitive science, after over two-decades of existence, continues to be a coherent, dynamic and highly interdisciplinary entity. Its interdisciplinary dimensions may be characterized as relatively stable, with psychology, particularly cognitive psychology, serving as the dominant locus discipline, and computer science, particularly artificial intelligence, serving as the second key target and source of interactivity. Linguistics, philosophy, neuroscience, and anthropology, in that order, serve as the other interdisciplinary affiliates. Recently, education has become a constituent discipline. During future time periods, however, one affiliate discipline might for a time dominate or lead overall research interactivity, and perhaps monopolize the selection of research themes. A relatively stable set of journals appears to be quite central to cognitive science research interactivity; *Artificial Intelligence, Brain, Cognition, Cognitive Psychology, Cognitive Science, Journal of Experimental Psychology-General, Journal of Experimental Psychology-Human Perception and Performance, Journal of Memory and Language, Language, Linguistic Inquiry, Linguistics, Memory & Cognition, Mind, Neuropsychologia, Psychological Review, and Trends in Neurosciences.* Journal clusterings reveal that research interactivity appears, after over two decades, to continue its bonding between its cognitive science center and psychology, computer science, linguistics and to a limited extent, neuroscience, philosophy. Anthropology's actual role in cognitive science appears to have been quite marginal. This multidisciplinary bonding appears to be stable, even though the underlying and specific research themes might be quite dynamic. Nevertheless, not much convergence between these various disciplines appears to have happened over in twenty years. The broad pattern of research interactivity suggests that cognitive science remains a diffuse and rather nebulous area, with relatively open boundaries. But two dominant schools of cognitive science (one based on mind and brain, and the other based on computation intelligence), continue to be side-by-side competitors and collaborators.

Appendix I

Journal Abbreviations

Abbreviation	Journal	Discipline
AAI	Applied Artificial Intelligence	CS
AANTH	American Anthropologist	ANTH
ACP	Applied Cognitive Psychology	PSY
AETHN	American Ethnologist	ANTH
AI	Artificial Intelligence	CS
AIM	AI Magazine	CS
ANAL	Analysis	PHIL
ANTH	Anthropos	ANTH
ANTHG	Anthropologie	ANTH
API	Applied Intelligence	CS
APL	Applied Psycholinguistics	LING
APSY	ACTA Psychologica	PSY
ARAN	Annual Review of Anthropology	ANTH
ARN	Annual Review of Neuroscience	NS
BBS	Behavioral and Brain Sciences	NS
BC	Brain and Cognition	NS
BCY	Biological Cybernetics	CS
BRN	Brain	NS
CACM	Communications of the ACM	CS
CANTH	Current Anthropology	ANTH
CI	Computational Intelligence	CS
CLAN	Cultural Anthropology	ANTH
CLNG	Computational Linguistics	LING
CNR	Cognitive Neuropsychology	PSY
COG	Cognition	PSY
COGD	Cognitive Development	PSY
COGS	Cognitive Science	PSY
CPSY	Cognitive Psychology	PSY
CRTX	Cortex	NS
DIAL	Dialectica	PHIL
DPSY	Developmental Psychology	PSY
ETHN	Ethnology	ANTH
ETHS	Ethos	ANTH
IEXP	IEEE Expert	CS
IJIS	International Journal of Intelligent Systems	CS
IJMM	International Journal of Man-Machine Studies	CS
ITMS	IEEE Transactions on Systems, Man, and Cybernetics	CS
ITNN	IEEE Transactions on Neural Networks	CS
ITPA	IEEE Transactions on Pattern Analysis and Machine Intelligence	CS
JCL	Journal of Child Language	LING
JCN	Journal of Cognitive Neuroscience	NS
JEPG	Journal of Experimental Psychology-General	PSY

Abbreviation	Journal	Discipline
JEPH	Journal of Experimental Psychology-Human Perception and Performance	PSY
JLING	Journal of Linguistics	LING
JMB	Journal of Mind and Behavior	PSY
JML	Journal of Memory and Language	PSY
JNP	Journal of Neurophysiology	NS
JNS	Journal of Neuroscience	NS
JPH	Journal of Phonetics	LING
JPIR	Journal of Psycholinguistic Research	LING
JPL	Journal of Philosophical Logic	PHIL
JPR	Journal of Pragmatics	LING
JSES	Journal of Social and Evolutionary Systems	ANTH
KACQ	Knowledge Acquisition	CS
KBS	Knowledge-Based Systems	CS
LANG	Language	LING
LCP	Language and Cognitive Processes	LING
LING	Linguistics	LING
LINQ	Linguistic Inquiry	LING
LPHIL	Linguistics and Philosophy	LING
MAN	Man	ANTH
MC	Memory & Cognition	PSY
META	Metaphilosophy	PHIL
MIND	Mind	PHIL
ML	Machine Learning	CS
MM	Minds and Machines	CS
MNST	Monist	PHIL
MSA	Metaphor and Symbolic Activity	LING
NC	Neural Computation	CS
NCMPT	Neurocomputing	CS
NN	Neural Networks	CS
NOUS	Nous	PHIL
NPSY	Neuropsychologia	NS
NS	Neuroscience	NS
PHIL	Philosophia	PHIL
PHR	Philosophical Review	PHIL
PHS	Philosophical Studies	PHIL
PPR	Philosophy and Phenomenological Research	PHIL
PPSY	Philosophical Psychology	PHIL
PRC	Pattern Recognition	CS
PRP	Psychological Reports	PSY
PRV	Psychological Review	PSY
SEMT	Semiotica	PHIL
TLING	Theoretical Linguistics	LING
TNS	Trends in Neurosciences	NS

Appendix II

Journal Influence within the Constituent Disciplines of Cognitive Science - 1982

Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
AETHN	0.004	0	*0.027	0.001	0	0.002	0.034
ARAN	0.002	0	*0.01	0.002	0.001	0	0.015
CANTH	0.004	0	*0.012	0	0	0.001	0.017
ANTH	0.001	0	*0.007	0	0	0	0.008
ETHS	0	0	*0.006	0	0	0	0.006
JSES	0	0	*0.002	0.002	0.003	0	0.007
MAN	0	0	*0.026	0	0.018	0.001	0.045
ANTHG	0	0	*0.003	0	0	0	0.003
ETHN	0	0	*0.022	0.002	0.002	0	0.026
AI	0	*0.01	0.001	0.01	0.002	0.023	0.046
ITPA	0	*0.016	0	0	0	0.005	0.021
BCY	0.006	*0.002	0.001	0	0	0.006	0.015
CACM	0	*0.028	0.002	0.013	0	0.011	0.054
PRC	0	*0.002	0	0	0	0	0.002
JLING	0.001	0	0.016	*0.029	0.002	0.004	0.052
APL	0.003	0	0.001	*0.002	0	0.002	0.008
LING	0.001	0.001	0.001	*0.114	0.016	0.001	0.134
JPIR	0.004	0	0.003	*0.024	0.003	0.015	0.049
LINQ	0	0.003	0.002	*0.072	0.003	0.01	0.09
LANG	0.001	0.003	0.008	*0.184	0.165	0.011	0.372
JCL	0	0	0.001	*0.029	0.001	0.014	0.045
JPH	0.001	0	0	*0.011	0.001	0.006	0.019
JPR	0	0	0.001	*0.002	0.003	0	0.006
LPHIL	0	0.022	0	*0.015	0.01	0.002	0.049
ARN	* 0.003	0.001	0	0	0	0	0.004
BRN	* 0.073	0.002	0.004	0.011	0.017	0.013	0.12
CRTX	* 0.031	0	0.001	0.006	0	0.008	0.046
NPSY	* 0.064	0	0.001	0.004	0	0.018	0.087
NS	* 0.024	0.002	0.002	0	0	0.003	0.031
TNS	* 0.005	0.001	0	0	0	0.001	0.007
JNP	* 0.042	0.016	0	0.001	0	0.006	0.065
JNS	* 0.222	0.005	0	0	0	0.001	0.228
BC	* 0	0	0	0.001	0.001	0	0.002
BBS	* 0.032	0.079	0.006	0.003	0.007	0.016	0.143
JPL	0	0	0	0.006	* 0.033	0	0.039
META	0	0	0	0	* 0.004	0	0.004
MIND	0.001	0	0.004	0.02	* 0.162	0.003	0.19
NOUS	0	0	0	0.008	* 0.087	0.001	0.096
PHIL	0	0	0	0.003	* 0.027	0	0.03

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Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
PHS	0	0	0	0.007	* 0.092	0	0.099
PHR	0	0	0.001	0.015	* 0.17	0.007	0.193
SEMT	0	0	0.001	0.009	* 0.006	0.001	0.017
MNST	0	0	0.002	0	* 0.067	0.003	0.072
PPR	0	0	0.001	0.002	* 0.031	0.001	0.035
ANAL	0	0	0	0.004	* 0.062	0	0.066
DIAL	0	0	0	0.002	* 0.014	0	0.016
APSY	0.018	0.001	0.002	0.005	0.001	*0.035	0.062
COG	0.006	0.002	0.005	0.042	0.018	*0.035	0.108
CPSY	0.012	0.005	0.021	0.049	0.003	*0.138	0.228
COGS	0.001	0.006	0.001	0.002	0.001	*0.013	0.024
JMB	0	0	0	0.004	0	*0	0.004
MC	0.013	0.001	0.015	0.02	0.001	*0.096	0.146
JML	0.01	0.003	0.027	0.049	0.004	*0.105	0.198
PRV	0.035	0.111	0.023	0.041	0.014	*0.191	0.415
PRP	0.003	0	0.001	0.001	0	*0.013	0.018
JEPH	0.014	0	0	0.002	0	*0.015	0.031
JEPG	0.011	0	0.003	0.004	0	*0.019	0.037

Journal Influence within the Constituent Disciplines of Cognitive Science - 1986

Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
AANTH	0	0	*0	0.001	0	0	1.001
AETHN	0	0	*0.046	0.001	0.001	0.002	1.05
ARAN	0	0	*0.02	0.001	0.001	0	1.022
CANTH	0	0	*0.011	0	0	0	1.011
ANTH	0	0	*0.006	0	0	0	1.006
ETHS	0	0	*0.007	0.001	0	0.001	1.009
JSES	0	0	*0.004	0.001	0	0	1.005
MAN	0	0	*0.032	0.002	0.023	0.003	1.06
ANTHG	0	0	*0.006	0	0	0	1.006
ETHN	0	0	*0.02	0	0	0	1.02
AI	0.002	*0.023	0.001	0	0	0.015	1.041
ITPA	0.001	*0.046	0	0.001	0	0.002	1.05
BCY	0.005	*0.004	0	0.001	0	0.006	1.016
CACM	0	*0.033	0	0	0.004	0.005	1.042
PRC	0	*0	0	0	0	0	1
IJMM	0	*0.003	0.001	0	0	0.002	1.006
JLING	0	0	0.017	*0.023	0.001	0.008	1.049
APL	0.002	0	0	*0.005	0	0.003	1.01
LING	0	0.004	0.005	*0.09	0.028	0.013	1.14
JPIR	0.002	0	0.002	*0.017	0.001	0.017	1.039
LINQ	0	0	0.007	*0.074	0.005	0.021	1.107
LANG	0	0.001	0.02	*0.162	0.125	0.023	1.331
JCL	0.001	0	0.003	*0.032	0.001	0.019	1.056
JPH	0	0	0.001	*0.004	0	0.008	1.013
JPR	0	0	0	*0.01	0.001	0.004	1.015
LPHIL	0	0	0.001	*0.015	0.018	0.004	1.038
ARN	* 0.006	0.002	0	0	0	0.001	1.009
BRN	* 0.057	0.003	0.003	0.005	0.045	0.024	1.137
CRTX	* 0.037	0	0.003	0.004	0	0.032	1.076
NPSY	* 0.056	0.001	0.003	0.004	0	0.035	1.099
NS	* 0.03	0.005	0	0.001	0.003	0	1.039
TNS	* 0.017	0.002	0	0.001	0	0.003	1.023
JNP	* 0.04	0.014	0	0.003	0.003	0.009	1.069
JNS	* 0.047	0.002	0	0	0	0.002	1.051
BC	* 0.012	0	0	0	0	0.009	1.021
BBS	* 0.02	0.004	0.01	0.008	0.031	0.034	1.107
JPL	0	0	0	0	* 0.017	0.001	1.018
META	0	0	0	0	* 0.008	0	1.008

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Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
MIND	0.001	0.001	0.002	0.015	* 0.179	0.006	1.204
NOUS	0	0	0	0	* 0.086	0.003	1.089
PHIL	0	0	0	0	* 0.02	0.003	1.023
PHS	0	0	0	0.003	* 0.082	0.004	1.089
PHR	0	0	0.003	0.017	* 0.159	0.003	1.182
SEMT	0	0	0.003	0.01	* 0.003	0.003	1.019
MNST	0	0	0.005	0	* 0.057	0.004	1.066
PPR	0	0	0	0	* 0.029	0.003	1.032
ANAL	0	0	0	0.002	* 0.068	0.002	1.072
DIAL	0	0	0	0	* 0.015	0	1.015
APSY	0.015	0	0.003	0.006	0.002	*0.036	1.062
COG	0.013	0.002	0.016	0.047	0.007	*0.069	1.154
CPSY	0.014	0.008	0.017	0.026	0.013	*0.135	1.213
DPSY	0	0	0	0	0	*0	1
CNR	0.003	0	0.001	0.002	0	*0.008	1.014
COGD	0	0	0	0.003	0	*0.002	1.005
COGS	0.003	0.012	0.01	0.003	0.008	*0.038	1.074
JMB	0	0	0	0	0	*0	1
MC	0.012	0.004	0.02	0.016	0.001	*0.093	1.146
JML	0.012	0.006	0.032	0.032	0.003	*0.111	1.196
PRV	0.028	0.018	0.025	0.031	0.006	*0.2	1.308
PRP	0.003	0.001	0	0.004	0	*0.008	1.016
JEPH	0.02	0.001	0.003	0.005	0	*0.03	1.059
JEPG	0.007	0.001	0.004	0.004	0	*0.028	1.044

Journal Influence within the Constituent Disciplines of Cognitive Science - 1990

Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
AANTH	0	0	* 0.001	0	0	0	1.001
AETHN	0	0	* 0.04	0	0.001	0.003	1.044
ARAN	0	0.001	* 0.024	0.003	0	0	1.028
CANTH	0.001	0	* 0.033	0.002	0.002	0	1.038
ANTH	0	0	* 0.007	0	0	0	1.007
ETHS	0	0	* 0.01	0	0	0	1.01
JSES	0	0	* 0.003	0.001	0	0	1.004
MAN	0	0	* 0.033	0	0.013	0.002	1.048
ANTHG	0	0	* 0.002	0	0	0	1.002
ETHN	0	0	* 0.019	0	0	0	1.019
NN	0.001	* 0.045	0	0	0	0.001	1.047
AI	0.003	* 0.347	0.001	0.005	0	0.023	1.379
AIM	0.003	* 0.06	0	0	0	0	1.063
ML	0.001	* 0.043	0	0	0	0.006	1.05
ITPA	0.001	* 0.095	0	0	0	0	1.096
BCY	0.011	* 0.027	0	0.006	0.002	0.007	1.053
IJIS	0	* 0.001	0	0	0	0	1.001
CACM	0.001	* 0.238	0	0.005	0.001	0.003	1.248
IEXP	0	* 0.011	0	0	0	0	1.011
PRC	0	* 0	0	0	0	0	1
IJMM	0	*0.03	0.001	0.002	0	0.006	1.039
JLING	0	0	0.019	* 0.023	0.001	0.006	1.049
APL	0	0	0	* 0.002	0.001	0.001	1.004
LING	0	0.004	0.003	* 0.082	0.01	0.01	1.109
LCP	0	0	0.002	* 0.01	0	0.011	1.023
JPIR	0.001	0	0.003	* 0.039	0.001	0.016	1.06
LINQ	0.001	0.001	0.004	* 0.088	0.005	0.015	1.114
LANG	0.001	0.001	0.016	* 0.226	0.108	0.017	1.369
JCL	0	0	0.001	* 0.042	0	0.017	1.06
JPH	0	0.001	0.002	* 0.008	0	0.005	1.016
JPR	0	0	0.001	* 0.013	0	0.002	1.016
LPHIL	0	0.001	0.002	* 0.042	0.015	0.003	1.063
TLING	0	0	0	* 0.001	0	0	1.001
MSA	0	0	0	* 0.002	0	0.001	1.003
ARN	* 0.019	0.008	0	0	0	0.008	1.035
BRN	* 0.059	0.003	0.001	0.012	0.025	0.027	1.127
CRTX	* 0.037	0.001	0.001	0.005	0.003	0.028	1.075
NPSY	* 0.065	0.002	0.003	0.011	0	0.044	1.125

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Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
NS	* 0.031	0.004	0	0	0	0.002	1.037
TNS	* 0.028	0.009	0	0	0	0.009	1.046
JNP	* 0.037	0.025	0	0.001	0	0.008	1.071
JNS	* 0.063	0.01	0	0	0	0.014	1.087
BC	* 0.025	0.001	0	0.004	0.001	0.009	1.04
BBS	* 0.018	0.013	0.011	0.019	0.011	0.049	1.121
JPL	0	0.005	0	0.007	* 0.015	0	1.027
META	0	0	0	0	* 0.006	0	1.006
MIND	0.001	0.001	0.002	0.017	* 0.177	0.004	1.202
NOUS	0	0	0.001	0.003	* 0.074	0.001	1.079
PHIL	0	0	0	0	* 0.017	0	1.017
PHS	0	0	0.001	0.002	* 0.084	0	1.087
PHR	0.001	0.002	0.003	0.01	* 0.125	0.005	1.146
SEMT	0	0.001	0.005	0.01	* 0.002	0	1.018
MNST	0	0.001	0.003	0.005	* 0.035	0	1.044
PPR	0	0.002	0	0	* 0.032	0	1.034
ANAL	0	0	0.001	0.003	* 0.039	0.001	1.044
DIAL	0	0	0	0.001	* 0.006	0	1.007
APSY	0.014	0.003	0.002	0.003	0	*0.036	1.058
ACP	0	0.001	0.001	0	0	*0.007	1.009
COG	0.013	0.012	0.012	0.091	0.014	*0.096	1.238
CPSY	0.015	0.015	0.011	0.056	0.004	*0.151	1.252
DPSY	0	0	0	0	0	*0	1
CNR	0.012	0	0.002	0.009	0	*0.017	1.04
COGD	0	0.001	0.001	0.015	0	*0.016	1.033
COGS	0.005	0.135	0.003	0.016	0.006	*0.047	1.212
JMB	0.002	0	0	0.016	0.004	*0	1.022
MC	0.01	0.006	0.015	0.03	0.004	*0.109	1.174
JML	0.012	0.007	0.021	0.085	0.003	*0.107	1.235
PRV	0.027	0.029	0.017	0.061	0.007	*0.204	1.345
PRP	0.001	0.001	0.002	0	0	*0.008	1.012
JEPH	0.027	0.01	0.006	0.007	0.004	*0.065	1.119
JEPG	0.011	0.007	0.007	0.017	0	*0.081	1.123

Journal Influence within the Constituent Disciplines of Cognitive Science - 1994

Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
AETHN	0	0	* 0.038	0.001	0	0	0.039
ARAN	0	0	* 0.023	0.003	0.002	0.002	0.03
CANTH	0.001	0	* 0.031	0.002	0.003	0	0.037
ANTH	0	0	* 0.004	0.001	0	0	0.005
ETHS	0	0	* 0.007	0.003	0	0	0.01
JSES	0	0	* 0.001	0.001	0.003	0	0.005
MAN	0	0	* 0.028	0.004	0.011	0	0.043
CLAN	0	0	* 0.018	0	0	0	0.018
ANTHG	0	0	* 0.004	0	0.002	0	0.006
ETHN	0	0	* 0.016	0.001	0.001	0	0.018
NC	0.003	0.064	0	0	0	0.003	0.07
NN	0.003	0.071	0	0	0	0.004	0.078
NCMPT	0	0.007	0	0	0	0	0.007
AI	0.004	0.187	0.001	0.008	0.007	0.021	0.228
AAI	0	0.003	0	0	0	0	0.003
AIM	0.003	0.053	0	0.003	0.001	0.006	0.066
ML	0.002	0.076	0	0.002	0	0.01	0.09
ITNN	0.001	0.056	0	0	0	0	0.057
ITPA	0.001	0.08	0	0	0	0.001	0.082
BCY	0.011	0.074	0	0	0.005	0.005	0.095
MM	0	0	0	0.003	0	0.002	0.005
IJIS	0	0.018	0	0	0	0.002	0.02
CACM	0	0.084	0	0.016	0.001	0.005	0.106
KBS	0	0.02	0	0	0	0	0.02
KACQ	0	0.022	0	0	0	0.001	0.023
PRC	0	0.001	0	0	0	0	0.001
IJMM	0.001	0.039	0	0.004	0.001	0.001	0.046
JLING	0.001	0	0.009	* 0.026	0.001	0.001	0.038
APL	0.001	0	0	* 0.006	0	0.003	0.01
LING	0	0.001	0.002	* 0.09	0.007	0.014	0.114
LCP	0.005	0.001	0.004	* 0.02	0	0.011	0.041
JPIR	0.005	0	0.002	* 0.023	0.001	0.013	0.044
LINQ	0.001	0	0.002	* 0.111	0.006	0.01	0.13
LANG	0.001	0.004	0.016	* 0.184	0.228	0.012	0.445
JCL	0.001	0.001	0.002	* 0.021	0.001	0.024	0.05
JPH	0.001	0	0.001	* 0.007	0	0.007	0.016
JPR	0	0	0.001	* 0.011	0	0.002	0.014
LPHIL	0	0.005	0	* 0.048	0.017	0.002	0.072

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Title	NS	CS	ANTH	LING	PHIL	PSY	Total IMP
MSA	0	0	0	* 0.001	0	0	0.001
ARN	* 0.031	0.011	0	0.002	0.001	0.015	0.06
BRN	* 0.068	0.003	0.002	0.017	0.042	0.031	0.163
CRTX	* 0.043	0.001	0	0.007	0	0.022	0.073
JCN	* 0.038	0.005	0	0.004	0.002	0.015	0.064
NPSY	* 0.081	0.004	0.001	0.011	0.002	0.042	0.141
NS	* 0.032	0.013	0	0	0.002	0.002	0.049
TNS	* 0.044	0.016	0	0.002	0.001	0.01	0.073
JNP	* 0.04	0.036	0	0.002	0.001	0.01	0.089
JNS	* 0.085	0.026	0	0.002	0.004	0.016	0.133
BC	* 0.035	0	0	0.003	0	0.017	0.055
BBS	* 0.022	0.038	0.008	0.012	0.037	0.056	0.173
JPL	0	0.01	0	0.005	* 0.035	0.002	0.052
META	0	0.001	0	0	* 0.004	0	0.005
MIND	0.001	0.015	0.004	0.024	* 0.217	0.004	0.265
NOUS	0	0.002	0	0.004	* 0.077	0	0.083
PHIL	0	0.004	0	0	* 0.011	0.001	0.016
PHS	0	0.01	0	0.008	* 0.093	0	0.111
PHR	0.001	0.009	0.002	0.009	* 0.132	0.006	0.159
SEMT	0	0	0.001	0.008	* 0.001	0	0.01
MNST	0	0	0	0.001	* 0.041	0.001	0.043
PPR	0	0.005	0	0	* 0.048	0	0.053
ANAL	0	0.001	0	0.005	* 0.068	0	0.074
DIAL	0	0	0	0.005	* 0.01	0	0.015
PPSY	0	0	0	0.004	* 0.003	0.004	0.011
APSY	0.011	0.004	0.001	0.006	0.004	* 0.034	0.06
ACP	0.001	0.001	0.001	0	0	* 0.008	0.011
COG	0.026	0.023	0.01	0.079	0.039	* 0.094	0.271
CPSY	0.023	0.021	0.011	0.051	0.016	* 0.124	0.246
CNR	0.028	0.001	0.001	0.011	0.002	0.015	0.058
COGD	0.001	0	0.001	0.008	0	0.021	0.031
COGS	0.008	0.091	0.005	0.018	0.004	0.044	0.17
JMB	0.001	0	0.001	0.015	0.002	0.001	0.02
MC	0.022	0.008	0.014	0.03	0.004	0.092	0.17
JML	0.021	0.008	0.014	0.065	0.006	0.086	0.2
PRV	0.05	0.038	0.015	0.047	0.014	0.178	0.342
PRP	0.001	0	0	0.002	0	0.007	0.01
JEPH	0.029	0.009	0.003	0.009	0.005	0.06	0.115
JEPG	0.02	0.011	0.006	0.007	0.002	0.084	0.13

Appendix III

Comparisons of Three Journal Citation Measures for 1994

IMP Rank	Journal (Abbreviation)	IMP	MSTD	MSTD Rank	INFL	INFL Rank	Discipline
1	Language (LANG)	1.44	17	1.63	3	4.93	LING
2	Psychological Review (PRV)	1.34	4	4.77	5	4.13	PSY
3	Cognition (COG)	1.27	11	2.44	22	1.15	PSY
4	Mind (MIND)	1.27	30	0.67	1	6.60	PHIL
5	Cognitive Psychology (CPSY)	1.25	10	2.91	4	4.45	PSY
6	Artificial Intelligence (AI)	1.23	24	1.02	19	1.39	CS
7	Journal of Memory and Language (JML)	1.20	12	2.37	11	1.85	PSY
8	Behavioral and Brain Sciences (BBS)	1.17	15	1.97	36	0.58	NS
9	Cognitive Science (COGS)	1.17	19	1.47	9	2.37	PSY
10	Memory & Cognition (MC)	1.17	13	2.20	20	1.36	PSY
11	Brain (BRN)	1.16	8	3.39	17	1.42	NS
12	Philosophical Review (PHR)	1.16	33	0.45	7	3.39	PHIL
13	Neuropsychologia (NPSY)	1.14	6	3.92	30	0.69	NS
14	Journal of Neuroscience (JNS)	1.13	1	9.04	35	0.58	NS
15	Journal of Experimental Psychology-General (JEPG)	1.13	14	2.04	8	2.77	PSY
16	Linguistic Inquiry (LINQ)	1.13	27	0.73	6	3.98	LING
17	Linguistics (LING)	1.12	28	0.71	13	1.73	LING
18	Journal of Experimental Psychology-HPP (JEPH)	1.12	9	3.16	26	0.92	PSY
19	Philosophical Studies (PHS)	1.11	42	0.24	33	0.62	PHIL
20	Communications of The ACM (CACM)	1.11	31	0.49	21	1.27	CS
21	Biological Cybernetics (BCY)	1.10	18	1.56	37	0.55	CS
22	Machine Learning (ML)	1.09	32	0.48	28	0.75	CS
23	Journal of Neurophysiology (JNP)	1.09	3	4.90	49	0.42	NS
24	Nous (NOUS)	1.08	44	0.21	23	1.12	PHIL
25	IEEE Transactions on Pattern Analysis and Machine						
26	Intelligence (ITPA)	1.08	37	0.34	45	0.47	CS
26	Neural Networks (NN)	1.08	26	0.75	60	0.23	CS
27	Analysis (ANAL)	1.07	48	0.18	24	0.99	PHIL
28	Cortex (CRTX)	1.07	2	5.14	14	1.73	NS
29	Trends in Neurosciences (TNS)	1.07	16	1.64	39	0.54	NS
30	Linguistics and Philosophy (LPHIL)	1.07	39	0.31	12	1.76	LING
31	Neural Computation (NC)	1.07	25	0.92	46	0.46	CS
32	AI Magazine (AIM)	1.07	29	0.68	10	2.22	CS
33	Journal of Cognitive Neuroscience (JCN)	1.06	20	1.38	31	0.68	NS
34	ACTA Psychologica (APSY)	1.06	22	1.13	15	1.49	PSY
35	Annual Review of Neuroscience (ARN)	1.06	7	3.69	2	5.77	NS
36	Cognitive Neuropsychology (CNR)	1.06	23	1.11	32	0.62	PSY
37	IEEE Transactions on Neural Networks (ITNN)	1.06	35	0.39	64	0.21	CS
38	Brain and Cognition (BC)	1.06	21	1.15	47	0.43	NS
39	Philosophy and Phenomenological Research (PPR)	1.05	54	0.12	42	0.51	PHIL
40	Journal of Philosophical Logic (JPL)	1.05	50	0.15	18	1.42	PHIL
41	Neuroscience (NS)	1.05	5	4.67	34	0.58	NS
42	Journal of Child Language (JCL)	1.05	38	0.34	27	0.81	LING
43	International Journal of Man-Machine Studies (IJMM)	1.05	43	0.23	63	0.21	CS

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IMP Rank	Journal (Abbreviation)	IMP	MSTD	MSTD Rank	INFL	INFL Rank	Discipline
44	Man (Man)	1.04	47	0.19	52	0.31	ANTH
45	Journal of Psycholinguistic Research (JPIR)	1.04	36	0.38	38	0.55	LING
46	Monist (MNST)	1.04	62	0.09	40	0.52	PHIL
47	Language and Cognitive Processes (LCP)	1.04	34	0.44	41	0.52	LING
48	American Ethnologist (AETHN)	1.04	46	0.19	69	0.12	ANTH
49	Journal of Linguistics (JLING)	1.04	45	0.21	29	0.75	LING
50	Current Anthropology (CANTH)	1.04	49	0.17	59	0.23	ANTH
51	Cognitive Development (COGD)	1.03	40	0.30	25	0.93	PSY
52	Annual Review of Anthropology (ARAN)	1.03	52	0.14	51	0.33	ANTH
53	Knowledge Acquisition (KACQ)	1.02	60	0.10	56	0.28	CS
54	International Journal of Intelligent Systems (IJIS)	1.02	58	0.10	65	0.19	CS
55	Knowledge-Based Systems (KBS)	1.02	67	0.05	66	0.17	CS
56	Journal of Mind and Behavior (JMB)	1.02	55	0.11	55	0.30	PSY
57	Cultural Anthropology (CLAN)	1.02	64	0.07	44	0.47	ANTH
58	Journal of Phonetics (JPH)	1.02	41	0.24	16	1.49	LING
59	Ethnology (ETHN)	1.02	63	0.08	43	0.48	ANTH
60	Philosophia (PHIL)	1.02	70	0.04	54	0.30	PHIL
61	Dialectica (DIAL)	1.02	57	0.10	57	0.28	PHIL
62	Journal of Pragmatics (JPR)	1.01	59	0.10	70	0.11	LING
63	Philosophical Psychology (PPSY)	1.01	68	0.05	73	0.07	PHIL
64	Ethos (ETHS)	1.01	61	0.09	48	0.43	PHIL
65	Semiotica (SEMT)	1.01	66	0.06	74	0.07	PHIL
66	Psychological Reports (PRP)	1.01	53	0.13	50	0.35	PSY
67	Applied Psycholinguistics (APL)	1.01	56	0.10	68	0.13	LING
68	Applied Cognitive Psychology (ACP)	1.01	51	0.14	61	0.23	PSY
69	Neurocomputing (NCMPT)	1.01	65	0.06	72	0.07	CS
70	Journal of Social and Evolutionary Systems (JSES)	1.01	72	0.03	58	0.27	ANTH
71	Anthropologie (ANTHG)	1.01	71	0.04	62	0.22	ANTH
72	Anthropos (ANTH)	1.01	69	0.04	67	0.16	ANTH
73	Metaphilosophy (META)	1.01	73	0.02	53	0.31	PHIL
74	Applied Artificial Intelligence (AAI)	1.00	74	0.02	77	0.04	CS
75	Minds and Machines (MM)	1.00	75	0.01	71	0.09	CS
76	Pattern Recognition (PRC)	1.00	79	0.00	79	0.00	CS
77	American Anthropologist (AANTH)	1.00	78	0.00	78	0.00	ANTH
78	Metaphor and Symbolic Activity (MSA)	1.00	76	0.01	75	0.06	LING
79	Applied Intelligence (API)	1.00	77	0.01	76	0.04	CS
80	Theoretical Linguistics (TLING)	1.00	80	0.00	80	0.00	LING
81	Developmental Psychology (DPSY)	1.00	81	0.00	81	0.00	PSY

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