THE FLORIDA STATE UNIVERSITY

COLLEGE OF COMMUNICATION

A CONTENT ANALYSIS OF CITATIONS TO J. C. R. LICKLIDER'S "MAN-COMPUTER SYMBIOSIS," 1960 - 2001: DIFFUSING THE INTERGALACTIC NETWORK

By

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For my family

and

in loving memory of Betty

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ABSTRACT

In 1960, J. C. R. Licklider, a well respected academician and professional, published an article entitled, “Man-Computer Symbiosis,” in the fledgling research journal, the *IRE* (Institute of Radio Engineers) *Transactions on Human Factors in Electronics*. Reflecting back on its publication, Internet historians and Internet pioneers consistently cite the influential nature of the article in predicting the Internet’s development. Using diffusion of innovations and the agenda-setting function as the theoretical framework, this study examines the influence network produced by a set of articles that cite Licklider from 1960-2001. The purpose of the study is to investigate the spread and influence of the ideas expressed in “Man-Computer Symbiosis” among published citing works in order to clarify our understanding about the article’s contributions. Diffusion of innovations assists in explaining the spread of Licklider’s ideas among citing authors. Agenda-setting offers insight into the events in Licklider’s career that positioned him to publish “Man-Computer Symbiosis” while also identifying the salience of particular ideas over others in citing authors’ works.

Citation analysis and quantitative content analysis are combined to produce the data set. Citation analysis identifies the influence network for “Man-Computer Symbiosis,” as represented by a set of citing authors. Quantitative content analysis examines the appearance of Licklider’s ideas within the article citations. Study results indicate that of the 110 citing articles examined, the idea for *symbiosis* was most frequently cited. In general, the hierarchy of ideas presented in “Man-Computer Symbiosis” was reflected overall in the citing authors’ hierarchy. The majority of citing authors were academicians affiliated with top-tier institutions who published in well-respected science/technology outlets. Citations to “Man-Computer Symbiosis” have remained relatively stable during a 40-year period, and the article continues to diffuse slowly but steadily among the research community.

CHAPTER ONE

INTRODUCTION

At the start of the Twenty-first Century, the Internet is a recently emerged household term in the United States and increasingly abroad that refers to a quick, convenient, and unparalleled means for communication and information retrieval via interconnected computers. A key to understanding the Internet's success is the process of digitization—the conversion of analog communication formats (e.g., light and sound waves) into binary code such that sound and video, for example, are all fundamentally represented as 1s and 0s or, more accurately, as two voltage levels: "on" and "off" (Microsoft, 1998). The ability to represent a variety of communication formats using this common language creates a hybrid channel whereby print, audio, and video are all accessed using a single electronic device, the computer. This process of combining traditionally distinct communication formats into a single digital format to create new uses, applications, and products is commonly referred to as convergence (Fidler, 1997). The networking of computers using a standard set of communication rules, or protocols (e.g., TCP/IP), further expands the usefulness of this common language by allowing individuals and groups using dissimilar hardware, software, and operating systems, to share information with one another across spatial and temporal boundaries at speeds comparable to, and in many instances greater than, traditional methods of information exchange.

Predominantly a U.S.-based technology in its design and development, the Internet is experiencing a fairly rapid rate of adoption since its release to the general public in 1994 (Pavlik, 1998). As of 2002, approximately 54% of individuals in the U. S. use the Internet (National Telecommunications and Information Administration, 2002). On the international front, Internet adoption is much slower at roughly 10% of the world's population having access, but access appears to be increasing steadily (Scopes Communications Group, 2002). Two driving forces behind the Internet's growing popularity are electronic mail (email), a primary mode of communication, and the World Wide Web, a graphically rich medium comprised of hyperlinked files that allow individuals to shop, to learn, and to express creative thoughts and works online. Additionally, newsgroups and discussion boards provide asynchronous, or delayed, communication between groups of people for purposes such as health related support groups and tips for repairing home appliances. Individuals can also participate in real time conversations using chat rooms, instant messaging (IM), and video conferencing technologies. Thus the Internet, for those who have access, conveniently combines the attributes of traditionally separate media—television, radio, and print—into a single format. Yet, where did the vision for this type of communication and information exchange begin?

Problem Statement

The Internet's physical origins stem primarily from the 1969 Advanced Research Projects Agency's (ARPA) computer networking experiment known as ARPAnet, in which four geographically separate and incompatible computers were successfully networked for data exchange over telephone lines. Histories recounting the Internet's development frequently reference a handful of pioneers and visionaries involved in transforming the idea for networked computing into a reality. Of these individuals, J. C. R. Licklider, a preeminent American scholar, frequently referred to as "Lick" by friends and colleagues, is credited with planting the Internet seed by promoting his vision of networked computing as early as the late 1950s; a time when computers were predominantly, if not exclusively, viewed as stand-alone calculating rather than communication and information exchange devices (Hafner & Lyon, 1996; Licklider, 1973; Segaller, 1999; Waldrop, 2001).

While it is difficult to pinpoint the exact origin of an idea, Larry Roberts, who in the late 1960s helped to build ARPAnet, specifically credited the concept of networked computing to Licklider saying, "The vision was really Lick's originally. None of us can really claim to have seen that before him nor [can] anybody in the world" (qtd. in Segaller, 1999, p. 40). Len Kleinrock, a UCLA researcher specializing in queuing theory and a participant in the original APRAnet experiment, confirms Robert's observation, when he reflected,

> Networking was one of [the Information Processing Techniques Office's (of which ARPA was a division)] major successes. They backed it fully; lots of money, lots of freedom in terms of what we were doing, really advanced technology. It was a great,

great experiment—I can't applaud them more. It was one of the great experiments in science, I think. It completely changed the ways things are going now—commerce, government, industry, science, etc. Who to thank? The key players at DARPA [Defense Advanced Research Projects Agency] for sure [Herzfeld, Taylor, Roberts]. But I think the originators of the whole ARPA concept—Licklider being one of them (Kleinrock, 1990, p. 29).

The focus of this study does not imply that only Licklider had the idea for networking computers. As history demonstrates time and again, ideas frequently originate from multiple individuals who may or may not coexist in time and who may either know of one another or not (Aikat, 2001). Additionally, ideas for networking the world via technology are longstanding, dating back to the Eighteenth Century (Mattelart, 2000). As such, this study does not intend to promote the view that the idea for interactive computing and later the Internet originated solely from Licklider—that would be too reductionistic and unlikely. Rather, this study is conducted from the perspective that of those who had ideas for networking computers, Licklider was, for a number of reasons to be examined, one of the earliest to clearly articulate and circulate his thoughts about this aspect of computing to the larger community of researchers who might then turn this vision into a reality.

Specifically, Licklider's 1960 article, "Man-Computer Symbiosis," is considered by many to be a watershed article that predicted the Internet's development (Brate, 2002; Hafner & Lyon, 1996; Packer & Jordan, 2001; Segaller, 1999). The consistency with which Internet researchers and developers cite Licklider generally, and "Man-Computer Symbiosis" specifically, supports this observation, as it signaled a turning point in how computers were viewed to present a vision for networking that is the essence of today's Internet. Yet, other than general histories about the Internet and its creators, little is written about the specific contributions of "Man-Computer Symbiosis" to the Internet's existence in light of a systematic examination of the article's spread and influence. Stephen Segaller (1999) offers further support for this observation in his Internet history,

> Under a succession of visionary leaders, *mostly still unknown and unrecognized* [emphasis added], the Information Processing Techniques Office (IPTO) would prove to be the division of ARPA that would in fact build the foundations of the networked information economy which surrounds us today. The first director of

IPTO was J.C.R. Licklider, the prophet of the "intergalatic computer network"… (Segaller, 1999, pp. 38-39).

Although current Internet histories provide a valuable overall context within which to view its conception, development, and effects, they are limited from more specifically examining individual contributions because they tend to focus on the macroscopic level. However, a greater understanding of individual contributions adds clarity to the more general understanding provided by current historical accounts regarding the Internet. The close examination of an early influential publication, in this case "Man-Computer Symbiosis," is one approach to gaining a more detailed understanding of a particular individual's contribution to the development of an innovation and the role of publication in disseminating ideas.

Research Questions

Given that Licklider is frequently credited with foretelling the Internet's existence and that "Man-Computer Symbiosis" is considered by many to be an important article contributing to this vision, this study is guided by two research questions:

RQ1 In Licklider's article, "Man-Computer Symbiosis," what ideas for improving the human-computer relationship were communicated to promote a research agenda for others to consider adopting?

RQ2 Among the authors citing "Man-Computer Symbiosis," what do the frequencies and patterns in citation to Licklider's ideas reveal about the article's spread and influence among these individuals?

The preceding questions are addressed first through a close reading of "Man-Computer Symbiosis" (1960) to identify the key ideas presented by Licklider and, second, through an analysis of citing articles published between 1960–2001 to examine the spread and influence of Licklider's ideas among these works. The theoretical framework for the study combines the diffusion of innovations and agenda-setting perspectives to examine these questions. Diffusion of innovations studies the process by which an innovation is communicated via certain channels among members of a social system over time (Rogers, 2003). Agenda-setting examines the process by which certain messages are made salient in the minds of others by individuals or groups who are in the position to promote these messages (Dearing & Rogers, 1996). Citation analysis and quantitative content analysis are the methods used to obtain data for the analysis.

Citation analysis is a data collection technique that is used to identify formal patterns of communication between authors, works, journals, disciplines, and geographical locations via the examination of reference lists to identify who is referencing whom, more formally referred to as the citation or influence network (Garfield, 1979; Harter, 1996; Palmquist, 1999). Quantitative content analysis is the systematic application of coding rules by multiple independent coders to categorize elements of a message and the subsequent numerical analysis of the relationships between these categories (Riffe, Lacy, & Fico, 1998). Both the theoretical framework and methods are detailed in subsequent chapters.

Justification of Study

Identifying and examining the ideas contained in "Man-Computer Symbiosis" and the articles that cite these ideas is important because it enables us to move beyond general statements regarding Licklider's contributions to present a more detailed analysis about the spread and influence of his ideas within a segment of the research community. Specifically, this analysis delves into the claim that Licklider's article "provided the road map" for future research on the human-computer relationship and computer networking (Waldrop, 2001, p. 175) by identifying the research agenda proposed in "Man-Computer Symbiosis" and the subsequent spread of these ideas over time among a group of citing works. More generally, this study furthers our understanding about the role that a scholarly publication plays in disseminating ideas within a community of researchers.

Goals of the Study

Underlying this study's justification is a set of goals that operate on three levels: the substantive, the theoretical, and the methodological. The substantive goals relate to the subject specific purpose of the study, to analyze the spread and influence of ideas published in "Man-Computer Symbiosis." The theoretical goals address the rationale for combining diffusion of innovations and agenda-setting to guide the analysis. The methodological goals relate to the underlying justification for combining citation analysis with quantitative content analysis to produce the study's data set. Each level is detailed in the remainder of this section.

Substantive Goals

As identified in the preceding discussion of the study's importance, the substantive goals of this research project are to 1) identify the key ideas communicated in "Man-Computer Symbiosis" and 2) examine the spread and influence of these keys ideas in works citing "Man-Computer Symbiosis" for the overall purpose of increasing our knowledge about the article's contribution to the larger research community. To date, numerous Internet histories promote "Man-Computer Symbiosis" as a watershed work that redefined the human-computer relationship (Brate, 2002; Hafner & Lyon, 1996; Packer & Jordan, 2001; Randall, 1997; Segaller, 1999; Waldrop, 2001). The perception of Licklider's 1960 article as an innovative work and Licklider himself as an innovative figure with respect to an early vision for the Internet is not limited to histories, however.

Textbooks, a primary educational tool in the academy, also promote the perception of Licklider as an innovator. For example, within the communication discipline two recent publications make specific reference to Licklider's contributions. In *Computer-Mediated Communication: Human-to-Human Communication Across the Internet* (Barnes, 2003), the author, tracing the development of human-computer interaction, signals Licklider's "Man-Computer Symbiosis" as one of the earliest formal and influential writings on the subject. On a more general level, *The New Mass Media* (Harper, 2000), traces the history of computer-mediated communication and begins by specifically naming Licklider as the one "who has been called the father of the Internet" (p. 31).

Beyond the realm of the academic textbook, cultural studies of the Internet foster a similar view of Licklider. To illustrate, in *Cyborg Citizen* (Gray, 2001) the author, writing about the human-computer relationship, states, "The very first technical use of the idea of human-computer symbiosis comes from J. C. R. Licklider's famous article 'Man-Computer Symbiosis'" (p. 167). That a number of publications serving a variety of purposes consistently cite the importance of "Man-Computer Symbiosis" to the development of the Internet is a driving force behind the questions asked in this study—the perception of an individual's contribution in relation to an in-depth examination of a particular manifestation of this contribution, the citation network in scholarly publications.

Theoretical Goals

On the theoretic level, this study combines diffusion of innovations and the agenda-setting function to examine the influence of "Man-Computer Symbiosis" in a way that differs from the mainstream use of these perspectives within the communication discipline (see Chapter Two for a more detailed explanation). Briefly, within communication, diffusion of innovations is applied primarily to study adopter categories, innovation characteristics, and communication channels in the context of news stories, health messages, and new technologies (e.g., cell phones, computers). Similarly, the agenda-setting function is frequently applied to studying news reports in the mass media. This study expands the use of diffusion of innovations and agenda-setting frameworks by using these perspectives to analyze the spread and influence of a set of ideas for a new communication technology in the realm of scholarly publication. Specifically, combining diffusion of innovations and agenda-setting to investigate the contributions of "Man-Computer Symbiosis" provides additional insight into the spread of his ideas by 1) identifying the research agenda as manifested in the key ideas he expressed and 2) tracing the dissemination of those ideas as manifested in their appearance among citing works across time.

Methodological Goals

The methodological goals for this study are three in number. First, this study expands upon previous research that has combined citation analysis and *qualitative* content analysis to investigate the influence of an author or publication. In comparison to qualitative content analysis, a more subjective data collection technique involving only a single individual's examination of message content, *quantitative* content analysis is more systematic in that it requires consistent application of coding rules by multiple independent coders and the use of reliability checks to ascertain the consistency with which the coding rules are applied. The benefit of a more systematic approach is that it provides a more defensible foundation upon which the results are based and claims of effect are made.

Second, combining citation analysis with quantitative content analysis demonstrates the ability to maximize the strengths of each method while minimizing their respective weaknesses. Citation analysis is useful for identifying influence networks as represented by citing works, but it is weak in revealing the context of the citations. Quantitative content analysis is useful for systematically identifying the context of messages, but it is weak in supporting claims about effects. Combined, citation analysis identifies the influence network for a publication (or source article) by using citations to the source article as a proxy for influence (or effect); and, content analysis identifies the substance of the citations by systematically examining them for the presence of information contained in the source article. Thus we are positioned better to discuss more specifically the effects of a source article on the articles that cite it. In this study, "Man-Computer Symbiosis" is the source article and the articles citing "Man-Computer Symbiosis" represent the influence network.

The third and final goal demonstrates the ability of quantitative content analysis to successfully examine content that possesses latent characteristics. With this method, content is divided into two broad categories: manifest and latent. Manifest content refers to surface level, directly observable content. An example of manifest content is author name (e.g., J. Smith) in an article. Author name is relatively straightforward to record and does not require the individuals (or coders) examining the content to determine the extent to which J. Smith is an author. Latent content refers to less directly observable content, such as character attractiveness in a television sitcom or the expression of an idea. Coding this type of content is more challenging because there is likely to be greater variation in coders' notions of what constitutes, for example, attractiveness or clear evidence for an idea's existence than there is in what indicates an article's author. This greater variation poses a threat to coders producing consistent coding results, a goal of quantitative content analysis. For this reason, some researchers argue that quantitative content analysis is only suited to studying manifest content (e.g., Holsti, 1969; Riffe et al., 1998) while others (e.g., Potter & Levine-Donnerstein, 1999) contend that latent content can be examined to ask more interesting questions than can be addressed by an analysis of manifest content alone.

This study examines a combination of manifest and latent content. Variables related to information about the articles citing "Man-Computer Symbiosis" are manifest (e.g., author name, year of publication). Variables related to the key ideas expressed in "Man-Computer Symbiosis" are latent in that we analyze citations for the presence of references to the key ideas contained in the source article. Ideas are abstract thoughts that can be difficult to identify concretely given variations in the language used to refer to an idea as well as changes in terminology and its meaning over time. However, if we successfully identify the presence or absence of these key ideas in the citing articles, we can provide more insightful and more interesting information about the contributions of "Man-Computer Symbiosis" to go beyond identifying who cited

Licklider when and where to answering what specifically was cited, how often, and in what patterns, with a high degree of confidence.

Summary

Given the rising popularity of the Internet, it is logical that scholars research the originators who promoted advancements in computing and networking. Internet histories consistently identify J. C. R. Licklider as one of the earliest individuals to clearly articulate a vision for networked computing that would eventually culminate in today's Internet. One of Licklider's earliest attempts at disseminating his idea to redefine the role of computers in society occurred in his 1960 publication entitled, "Man-Computer Symbiosis." Although frequently cited as a germinal article in the area of human-computer interaction, less is known specifically about the article's contributions. Guided by diffusion of innovations and agenda-setting and combining citation analysis and quantitative content analysis, this study builds upon the oral histories of various Internet pioneers and the interpretations of historical researchers to produce an empirical analysis of the spread and influence of specific ideas contained within "Man-Computer Symbiosis" among citing works within the larger research community.

This study makes contributions on three levels: substantive, theoretical, and methodological. Substantively, it brings Licklider's contribution with respect to "Man-Computer Symbiosis" into sharper focus than has been obtained in previous writings that summarize his work. In turn, the findings in this study may then be used to support or possibly to raise questions related to claims regarding Licklider's influence with respect to the human-computer relationship. More generally, this study promotes understanding about the functions scholarly publications serve in the research community by identifying and examining the influence network generated by a particular publication. Theoretically, the study expands upon the application of the diffusion of innovations and agenda-setting perspectives within the communication discipline by applying them to a less researched topic. Methodologically, the study builds upon past studies that combined citation analysis with content analysis through the specific application of *quantitative* content analysis that maximizes the strengths of each method while minimizing their limitations and produces a more defensible set of results. The study further demonstrates that quantitative content analysis is able to successfully analyze content possessing latent characteristics.

Chapter Organization

A number of steps corresponding to the organization of this dissertation are necessary to accomplish the goals previously outlined. Chapter Two provides the historical context for the study and begins with a brief biographical account of Licklider's youth, education, and career up to the 1969 ARPAnet experiment. The chapter then provides a broad overview of the social, political, and economic climate in which Licklider's work was conducted, followed by a general summary of computing that identifies some of the key individuals with whom Licklider interacted and by whom he was influenced. At the chapter's end, the results of a close reading conducted on "Man-Computer Symbiosis" are presented to identify the key ideas that are then traced in subsequent publications citing this work.

Chapter Three presents the theoretical framework for the study in detail. The chapter begins with a synopsis of scholarly publication and those who typically engage in the process, given that this is the social system of interest to the study. Next, a detailed discussion of diffusion of innovations related to its purpose, history, strengths and limitations, and relevance to the study is presented. This is followed by an overview of agenda-setting that addresses similar points. A discussion of the study's rationale as it relates to the guiding research questions completes the chapter.

Chapter Four details the two methods used to collect data for the study: citation analysis and quantitative content analysis. Beginning with citation analysis, each method is presented in terms of its uses, strengths, limitations, and relevance to this study. The benefits of combining the methods are then broadly outlined. A detailed research plan follows that addresses the specifics of the study with respect to each method. It includes information about the selection process used to identify the set of citing articles examined, the units of analysis and the variables coded, and coding rules and coder trainer. The chapter concludes with a discussion of the data analyses appropriate for the study based on the characteristics of the data set, the level of measurement of the data, and the guiding research questions.

Chapter Five presents the results of the study based on the statistical analyses conducted. Results of the intercoder reliability checks are presented first, as these speak to the quality of the data set produced by the quantitative content analysis. Primary data analyses follow the intercoder reliability section to present descriptive summaries of the variables examined. Secondary analyses that follow up on questions raised by the primary data results are then presented. Lastly, tests analyzing independence and covariance between variables provide additional insight into the spread and influence of "Man-Computer Symbiosis" among the citing articles examined.

Chapter Six summarizes the study results and discusses the results within the context of the substantive, theoretical, and methodological goals of the study. Based on the study results, the chapter addresses questions such as: Did "Man-Computer Symbiosis" set a research agenda? Is "Man-Computer Symbiosis" an important article? It also comments on the extent to which the combined theories and methods aligned to produce a successful study.

Chapter Seven concludes the dissertation with a discussion of the limitations and strengths of the study. This section is followed by the identification of areas for future research specific to the topic of study, and the theories and methods used. The chapter closes with general summary remarks about the contributions of "Man-Computer Symbiosis" to research on interactive and networked computing.

CHAPTER TWO

HISTORICAL CONTEXT

When examining the spread and influence of a set of ideas over time, it is useful to first situate the analysis within a broader context given that ideas do not spring fully formed from a vacuum; rather, they form out of a complex mix of personal, social, political, and economic factors, to name a few. This chapter begins by situating Licklider's work within a body of literature that recognizes the importance of his contributions to the development of interactive computing, particularly with respect to "Man-Computer Symbiosis." The chapter then presents an historical overview of several key individuals and developments related to computing that contributed to Licklider's vision of a symbiotic relationship between the human being and the computer. Beginning with a brief synopsis of Licklider's youth and educational background, the chapter proceeds to trace his career path, along with a more general history of computing up to the 1969 ARPAnet experiment, the Internet's forerunner. The chapter concludes with a presentation of the key ideas contained in "Man-Computer Symbiosis" that are subsequently analyzed in the context of the influence network produced by articles citing this article.

The Influential Nature of "Man-Computer Symbiosis"

As noted in the Introduction to this study, a number of texts cite Licklider's article, "Man-Computer Symbiosis," as a watershed piece that predicted the rise of interactive and networked computing. The frequent reference to Licklider's article particularly in Internet histories forms the basis from which this study begins—by accepting the notion that "Man-Computer Symbiosis" was a founding article in the development of interactive and network computing. The following examples from various texts highlight how Licklider in general and "Man-Computer Symbiosis" in particular are portrayed over time.

Internet histories:

- Hafner & Lyon (1996). *Where wizards stay up late*.
  "Lick's thoughts about the role computers could play in people's lives hit a crescendo in 1960 with the publication of his seminal paper 'Man-Computer Symbiosis' … In the moment that Licklider published the paper his reputation as a computer scientist was fixed forever" (pp. 34-35).

- Packer & Jordan (2001). *Multimedia: From Wagner to virtual reality*.
  Features a chapter dedicated to the article, "Man-Computer Symbiosis."
  "With this article, Licklider fundamentally changed how we interact with computers by proposing the novel idea of a symbiotic relationship between man and machine … This foresight was extraordinary considering that 'Man-Computer Symbiosis' was written when computers were excruciatingly slow and clumsy, with mainframe systems using punch card input and teletype output the norm" (p. 56).

- Randall (1997). *The soul of the Internet: Net gods, netizens and the wiring of the world*.
  "One name that keeps recurring in discussions about the Internet's early days is J. C. R. Licklider … In [1960] he published an important paper called *Man-Computer Symbiosis* that demonstrated his commitment to computer networking as a focus of human communication" (p. 12).

- Segaller (1999). *Nerds 2.0.1: A brief history of the Internet*.
  "The first director of IPTO was J. C. R. Licklider, the prophet of the 'intergalactic network' … In 1960, Lick had published a memorable and influential paper, 'Man-Computer Symbiosis,' in which he had set out some of the prophetic ideas he had for such implementation of computers" (p. 39).

Oral histories:

- Charles Herzfeld (1990). *Oral history 208*. Charles Babbage Institute.
  Second director of ARPA; he authorized Bob Taylor to proceed with the ARPAnet

experiment. Recalling Licklider's lectures on modern computing that he attended: "They predicted the future of computing in America remarkably well, number one. I mean they said, 'We clearly can do the following. It makes sense and we ought to do it, so let's go do it.' And indeed, it happened. Networking, interactive graphics, time-sharing, and all these things that are now commonplace were in the air, and he [Licklider] saw to it that they would happen" (p. 5-6).

- Len Kleinrock (1990). *Oral History 190*. Charles Babbage Institute.
  Speaking about the contributors, of which he was one, to the development of ARPAnet, the Internet's forerunner:
  "…Who to thank? The key players at DARPA [Defense Advanced Research Projects Agency] for sure [Herzfeld, Taylor, Roberts]. But I think the originators of the whole ARPA concept—Licklider being one of them" (p. 29).

- Larry Roberts (1989). *Oral History 159*. Charles Babbage Institute.
  Roberts was an original team member of the ARPAnet project. Recalling some of the early thinking on networked computing:
  "So, what I concluded was that we had to do something about communications, and that really, the idea of the galactic network that Lick talked about, probably more than anybody, was something that we had to start seriously thinking about. So in a way networking grew out of Lick's talking about that, although Lick himself could not make anything happen because it was too early when he talked about it. But he did convince me it was important" (p. 10).

- Bob Taylor (1989). *Oral History 154*. Charles Babbage Institute.
  Taylor directed the team that initiated the plans to produce ARPAnet.
  "…the reason I moved from the NASA position [to ARPA] is fundamentally because over time, I became heartily subscribed to the Licklider vision of interactive computing. The 1960 man-computer symbiosis paper [that Licklider wrote] had had a large impact on me" (p. 5).

New media texts:

- Gray (2001). *Cyborg Citizen*.

  "The very first technical use of the idea of human-computer symbiosis comes from J. C. R. Licklider's famous article 'Man-Computer Symbiosis'" (p. 167).

From these varied accounts, it becomes clear that Licklider and his publication were and continue to be regarded as very influential in the development of interactive and networked computing that we experience today. As we shall see in the following section, Licklider was a highly intelligent and motivated individual who had an interesting and varied career path; computing was not his original area of study.

J. C. R. Licklider

Born on March 11, 1915 in St. Louis, Missouri, Joseph Carl Robnett Licklider grew up as the inquisitive only child of Margaret and Joseph Licklider, possessing "a lively sense of fun, an insatiable curiosity, and an abiding love of all things technological" (Waldrop, 2001, p. 8). Licklider remained inquisitive and fascinated by technology throughout his youth and as an undergraduate at Washington University, where he studied physics, mathematics, and psychology to eventually earn a triple degree in 1937. He earned a master's in psychology from the same university a year later and then entered the doctoral program at the University of Rochester in 1938, where his dissertation "made what may well have been the first maps of neural activity on the auditory cortex," identifying the areas responsible for interpreting sound frequencies (p. 13). Upon completion of the doctorate, Licklider accepted a postdoctoral appointment at Swathmore College to continue his studies in "physiological" psychology, known today as neuroscience.

In 1942, with WWII underway, Licklider accepted a position in Leo Beranek's Psycho-Acoustics Lab at Harvard where he focused on "the process of speech understanding" in the presence of signal distortion (Waldrop, 2001, p. 15). Interestingly, Leo Beranek would later form Bolt, Beranek, & Newman (BBN), the company that built the Internet's predecessor, the ARPAnet. From Harvard, Licklider moved on to the Acoustics Laboratory at MIT in 1950 and then a year later to MIT's Lincoln Laboratory, where in 1952 he was greatly influenced by the human-computer relationship created by the Semi-Automatic Ground Environment (SAGE) project, initially referred to as Project Charles. With the SAGE system, human operators used the first light gun technology to retrieve aircraft coordinates from a computer radar screen. A few years later in late 1956-early 1957, Licklider met Wesley Clark serendipitously in the basement of MIT's Lincoln Laboratory, where both men worked. Clark introduced Licklider to the computing advances of the TX-2, a computer "which contained 64,000 bytes of memory (as much as a simple handheld calculator today) [and that] took up a couple of rooms" (Hafner & Lyon, 1996. p. 33). Importantly, the TX-2 used video screens to display information thus enabling Clark to illustrate for Licklider the potential for increased human-computer interactive use. According to Hafner & Lyon,

> The sessions with Clark made an indelible impression on Lick. He drifted further from psychology and toward computer science. As his interests changed, Lick's belief in the potential for computers to transform society became something of an obsession. Succumbing to the lure of computing, he began spending hours at a time at the interactive display console (p. 34).

These early marathon sessions helped to shape Licklider's notion for a human-computer partnership.

In 1957, Licklider joined Leo Beranek's private company, Bolt, Beranek, & Newman (BBN), which specialized in acoustical engineering. Bringing along his enthusiasm from the work with Clark, Licklider was instrumental in expanding the company's focus to include computer research and development. In 1960, while working for BBN, Licklider published "Man-Computer Symbiosis," outlining a new vision for the human-computer relationship.

Two years later, in 1962, Licklider left BBN to head the Information Processing Techniques Office (IPTO) of the U.S. government's Advanced Research Projects Agency (ARPA), where he remained until 1964. Here he continued to explore, refine, and fund his ideas for human-computer symbiosis and computer networking (Hafner & Lyon, 1996). During his tenure at ARPA, Licklider formed a group of closely-knit computer scientists he referred to, somewhat in jest, as the "Intergalactic Computer Network" (p. 38). Although the phrase originally referred to a group of computer scientists, "[Licklider] would extend the concept of the Intergalactic Network to mean not just a group of people to whom he was sending memos but a universe of interconnected computers over which all might send their memos" (p. 38).

Notably, five years after Licklider left the IPTO and returned to MIT, Bob Taylor (Licklider's successor after Ivan Sutherland), coordinated the design and implementation of the

ARPAnet experiment (Taylor, 1989). Bob Taylor's presence at ARPA was not happenstance. In a 1989 interview, Taylor reported, "…the reason I moved from the NASA position [to ARPA] is fundamentally because over time, I became heartily subscribed to the Licklider vision of interactive computing. The 1960 man-computer symbiosis paper [that Licklider wrote] had had a large impact on me" (p. 5). The ARPAnet successfully linked four geographically distinct computers (or nodes) located at Stanford Research Institute, University of California at Los Angeles, University of California at Santa Barbara, and University of Utah for data exchange via broadband, 50-kilobit-per-second, lines supplied by AT&T (Segaller, 1999). The year was 1969; nine years after "Man-Computer Symbiosis" made its debut. A first step toward creating the Intergalactic Network had been taken.

ARPAnet and Beyond

In the roughly thirty-five years it took before the Internet gained the attention of the American public in the early 1990s, several individuals played important roles in helping the APRPAnet experiment evolve into today's Internet. In addition to Bob Taylor, examples of other notable individuals who participated in the ARPAnet experiment include: Larry Roberts, Len Kleinrock, and Frank Hart (Hafner & Lyon, 1996; Segaller, 1999). Roberts was recruited by Taylor to work on the ARPAnet project because he was one of the few individuals at the time who had successfully networked two computers together. Len Kleinrock at UCLA worked on the packet switching technology, as did Paul Baran at the Rand Corporation, which controlled data flow in the network. When the ARPAnet contract was awarded to BBN, the larger telephone and computer corporations were uninterested in the project, Frank Hart coordinated the team of professionals who built the network.

Upon the successful completion and demonstration of the ARPAnet, work on computer networking gained the interest of numerous individuals. Some of the individuals who played major roles in moving us toward today's Internet and its applications include: Vinton Cerf and Bob Kahn, Bob Metcalfe, Ray Tomlinson, and Tim Berners-Lee (Hafner & Lyon, 1996; Segaller, 1999). Vinton Cerf and Bob Kahn developed TCP/IP, Transmission Control Protocol/Internet Protocol, which standardized the transfer of digital information in networks. Bob Metcalfe co-invented Ethernet with David Boggs at Xerox Parc, a technology that allowed local networks of personal computers to be created. Ray Tomlinson of BBN spliced two software programs together to create the Internet's most often used application, email. Tim Berners-Lee invented the World Wide Web, a popular Internet application that enables the exchange of text, graphics, and sound. The efforts of these individuals, in turn, helped the designers and manufacturers of personal computers, such as Microsoft's Bill Gates and Apple's Steve Jobs, to expand the relevance and use of these machines to a larger public, an ultimate goal of Licklider's symbiotic vision. For the purposes of this study, however, the focus is mainly on the early history of computing and the 1960s when the early conceptualization for interactive and networked computing was taking place.

An Overview of the Economic, Political, and Social Climate

Generally speaking, in the United States, researchers of Licklider's generation were greatly influenced by the events of WWI and WWII, as well as the Great Depression and the Cold War. Given the vast amount of destruction both physically and psychologically of the two World Wars, in addition to the economic ruin of many Americans (including Licklider's father) during the Depression, it is not surprising that Licklider set his sights on ideas to benefit human-kind generally. Nor was Licklider alone in holding this perspective.

The science fiction movement of the early to mid 1900s, built upon a mix of utopian and dystopian perspectives that sought to imagine, to expose, and to reconcile the promise and perils of human potential through futuristic thinking in which technology played a pivotal role. Examples of individuals who were thinking about the future role of technology in society around the time that Licklider was formulating his thoughts on the human-computer relationship include Isaac Asimov, Gene Roddenberry, George Orwell, and Marshall McLuhan. Each of these individuals was interested in the possible effects of increased interaction between humans and their technological creations.

In 1950, Soviet born Isaac Asimov published *I, Robot* introducing the Three Laws of Robotics, which emphasized the interactive benefits and subservience of robots to humans and greatly influenced future writings about robotics ("Isaac Asimov," 1997). Over a decade later, Gene Roddenberry, an American writer, created the first screenplay for a proposed television series entitled *Star Trek*, a utopia-based story founded on the premise of a technologically integrated "future in which a united Earth would work together with other alien worlds to create a Federation, which would then dispatch giant starships throughout the galaxy 'to boldly go where no man has gone before'" ("Gene Roddenberry," 2000). On the other end of the spectrum, George Orwell's classic 1949 dystopian text entitled, *Nineteen Eighty-Four*, depicted a world cast into doom due, in part, to the misuse of technology by reigning powers to infiltrate the everyday lives of humans, thus turning the human race into a collective of mindless drones who served a privileged few ("George Orwell," 2002). And somewhere in between the utopian and dystopian perspectives stood Marshall McLuhan, a Canadian scholar best known for his musings—"the medium is the message"—about the role of mass media in society. McLuhan's first published work, *The Mechanical Bride: Folklore of Industrial Man* (1951), examined the intersection of humans and machines, primarily within the realm of advertising, and speculated about the effects of that intersection on culture and society ("(Herbert) Marshall McLuhan," 2002).

In the realm of computing, like many of his contemporaries, Licklider saw the promise for improving the human-computer relationship and of interconnecting humans through machines in an effort to improve the overall quality of life for people worldwide. This is not to say that Licklider disregarded the destructive potential of technology. In fact, he was known to echo the sentiments of Norbert Wiener, a preeminent mathematician and military researcher who was horrified by the contribution of science and technology to the decimation of Hiroshima and Nagasaki, commenting, "If all the Industrial Revolution accomplished was to turn people into drones in a factory then what was the point?" (qtd. in Waldrop, 2001, p. 98). Despite or perhaps because of this troubling question, Licklider committed himself to finding ways to improve human-computer relations in an effort to free people for higher intellectual and creative pursuits.

A Brief Overview of Computing

The increased use of computers worldwide during the later half of the Twentieth Century suggests a short history for the technology. However, the history of computing dates much farther back in time. For most of their existence, however, computers have been primarily viewed as calculating devices used to manipulate numbers that represented a variety of phenomena. According to computer historians, the road to computing begins with the quantification or enumeration of people, objects, and so on, that originated with early human civilization when tallies were etched into scraps of bone for counting such things as the members of a tribe, livestock in a herd, or the passing of the seasons (Aikat, 2001; White, 1999).

The creation of a number system fostered a desire to manipulate—to add, subtract, divide—these quantities in the quest to represent and to understand the world better. The abacus, developed in China, is one of the earliest known (human powered) calculating devices, dating back to at least 2600B.C. (White, 1999). In time, however, as calculations became more complex inventors grew interested in automating this process through mechanization. Leonardo Davinci, for example, drew out plans for one of the earliest mechanical calculators. Other examples include Charles Babbage's Analytic Engine in 1830, Herman Hollerith's 1888 tabulating machine that used punch cards and successfully tallied the 1924 U.S. census (later, Hollerith founded International Business Machines, IBM), and Vannevar Bush's 1933 Differential Analyzer, a complex mechanical computer that solved partial differential equations. Although the Differential Analyzer, for example, greatly increased the speed of calculation, a simple problem often took days for researchers to set up, more the norm than the exception with early computers. In time, others saw the possibility of shifting from a mechanically based computer to one based on electronic components. Claude Shannon's master's thesis on electronic switching further advanced the binary language of computing and is considered to be one of the most significant contributions to the advancement of computing overall because it fostered a shift from analog to digital computing (Waldrop, 2001).

It is important to note here that military applications of computing were a driving force behind many of the advances made in computer technology, particularly during wartime. ENIAC, the Electronic Numerical Integrator Analyzer and Computer, built in the 1940s, is an early example of electronic computing. ENIAC calculated missile trajectories for the U.S. Army; however, the use of vacuum tubes—the reigning technology at the time—greatly compromised the machine's usefulness because the extreme heat generated by the tubes caused frequent meltdowns of the computer's parts. The SAGE system, mentioned earlier as influencing Licklider's view on the interactive potential of computers, was part of the Distance Early Warning (DEW) defense initiative that linked a series of radars spanning "from Hawaii to Alaska, across the Canadian archipelago to Greenland, and finally to Iceland and the British Isles" (Hafner & Lyon, 1996). The main purpose of SAGE was to receive and interpret data from detection and tracking radar and to position defensive weaponry at incoming aircraft identified as hostile. The system was semi-automatic in that human operators were still an essential part of the system's functioning. However, unlike the standalone ENIAC, the SAGE system was an early example of a real-time interactive system that combined human and computing power for the purpose of problem solving. More specifically,

> Operators communicated with the computer through displays, keyboards, switches, and light guns. Users could request information from the computer and receive an answer within a few seconds. New information continuously flowed directly into the computer's memory through telephone lines to the users, making it immediately available to the operators (p. 31).

More broadly, the 1957 launching of the Russian satellite, Sputnik, during the height of the Cold War set in motion a chain of events that resulted in the Space Race between the U.S. and the Soviet Union; a race in which computers and their technological advancement figured prominently (Segaller, 1999).

On the business front, as Licklider promoted his ideas for human-computer symbiosis between 1958 and 1969, corporate giants such as IBM (International Business Machines) and AT&T (American Telephone & Telegraph) were logical candidates to participate in developing this relationship. However, both companies remained largely disinterested in the concept (Hafner & Lyon, 1996). IBM, a prominent computer manufacturer who Licklider worked for briefly (and unhappily), was heavily invested in its room-sized stand alone computers and was resistant initially to even considering developing time-sharing computers, an element crucial to creating Licklider's symbiotic relationship (Waldrop, 2001). AT&T, a telecommunications giant, was also heavily invested in its infrastructure, viewing it as the perfect voice data transmission network. Neither company saw the practicality or potential for profit in a computer network and each assumed no one else would see these benefits either. This perception persisted with the development of the APRAnet; though AT&T would supply the data transmission lines for the project, this was the extent of its investment in the experiment (Segaller, 1999).

While individuals struggled and experimented with the physical makeup of computers, others focused on the more conceptual, abstract elements of computer design. In 1936, for example, Alan Turing theorized on the ultimate unpredictability of knowing exactly how a computer would "behave." Turing concluded that trial and error was, and is, the only way to know what a computer will do, hence the constant need for beta-testing and "debugging" of programs (Turing, 1936). Another facet of Turing's work that is still with us to today is the Turing test, an assessment of artificial intelligence, which assesses a computer's ability to convince a human that s/he is interacting with another human instead of a computer program (Brate, 2002).

In 1945, John von Neumann conceptualized the step-by-step functioning of computers that is still with us today in his draft of the EDVAC (Electronic Discrete Variable Automatic Computer) paper. In the same year, Vannevar Bush (1945) published “As We May Think,” a prescient article that laid out the early idea for what we refer to today as *hypertext*. At the time of Bush’s publication, microfilm was the emerging technology in information storage and retrieval—computers were not advanced enough to catch his attention—and he proposed a system whereby information would be linked via association between concepts, similar to how the human mind works in linking discrete bits of information into a more complex whole. In the late 1940s, Norbert Wiener, among others, championed a new science, Cybernetics. Cybernetics combined the concepts of communication, control, feedback, and networking to create a perspective that ran counter to B. F. Skinner’s reining worldview of humans as simple stimulus-response machines. Wiener refashioned humans as “‘machines’ of a new kind, embodying purpose—and thus, autonomy” (Waldrop, 2001, p. 92) and he drew parallels between humans and computing machines in this regard (Wiener, 1948). Wiener (1950) emphasized the importance of studying the role of control, which he defined as “the sending of messages which effectively change the behavior of the recipient,” in the communication process (p. 8). Thus, cybernetics concerned itself with the exchange of messages via “communication facilities” between humans and machines, machines and humans, and machines and machines. During this time, Licklider attended Wiener’s lecture series at Cambridge and was greatly influenced by Wiener’s ideas, commenting that, “Digital stuff was big in all of that” (Licklider, 1988, p. 13).

Licklider and the Human-Computer Relationship

In *Technomanifestos: Visions from the Information Revolutionaries*, Brate (2002) organizes the development of the Information Age into four distinct phases: frontier, revolution, power, and symbiosis. He presents the compelling argument that the works of Wiener, Bush, Turing, and von Neumann, which he places in the “Frontier” phase, advanced computing technology, at least conceptually, to the point that subsequent individuals were able to foresee the expanded role of computers in human affairs. Importantly, Brate presents Licklider as the first individual in the subsequent “Revolution” phase stating, “Licklider would quietly lay the groundwork for an open network that allowed everyone to communicate and share computing power" (p. 87). Hence, computing advances by individuals such as Bush, Turing, von Neumann, and Wiener were not lost on Licklider. Nor, given Licklider's background in neuroscience, were parallel advances in neural network theory that viewed the brain as a series of neurons (or nodes) interconnected via multiple pathways. In time, it can be deduced that Licklider saw computers in a similar light. That is, computers could function as information nodes interconnected by data transmission lines to form a network for sharing data and, more importantly, for supporting communication between people. His vision occurred in the late 1950s, a time when computers were mainly, if not exclusively, conceived of and used as stand-alone calculators. The scholarly journal was one channel by which Licklider communicated this vision.

In 1960, while working at BBN, Licklider published "Man-Computer Symbiosis" in the *IRE* (Institute of Radio Engineers) *Transactions on Human Factors in Electronics*. Notably, it was the lead article in the first issue of the first volume published for the Transactions. According to Waldrop (2001), the article was written as a favor—Licklider "hated to write"—to Jerry Elkind, whom Licklider had formerly mentored at MIT in the early 1950s (p. 176). In Licklider's words, "'Man-Computer Symbiosis' was largely about ideas for how to get a computer and a person thinking together, sharing, dividing the load…" (Licklider, 1988, p. 22).

Five years later, in 1965, Licklider advanced the ideas contained in his 1960 article in "Man-computer Partnership," published in *International Science and Technology*. In 1968, a third related article, co-authored with Bob Taylor, entitled, "The Computer as a Communication Device" was published in *Science and Technology*. Of these three publications dealing with human-computer interactions (Licklider wrote numerous articles throughout his career), the 1960 publication is cited in Internet and biographical histories as an early influential article in human-computer interaction and computer networking (Hafner & Lyon, 1996; Gale Group, 2000; Packer & Jordan, 2001; Segaller, 1999; Waldrop, 2001). It is of particular interest to this study given the popularity of today's Internet, a technology predicted in the article.

"Man-Computer Symbiosis"

Considered a watershed article in the area of human-computer relations, Licklider's "Man-Computer Symbiosis" opened with the following biological scenario:

> The fig tree is pollinated only by the insect *Blastophaga grossorum*. The larva of the insect lives in the ovary of the fig tree, and there it gets its food. The tree cannot reproduce without the insect; the insect cannot eat without the tree; together, they constitute not only a viable but a productive and thriving partnership. This cooperative "living together in intimate association, or even in close union, of two dissimilar organisms" is called symbiosis (Licklider, 1960, p. 4).

From this scenario, Licklider predicted a parallel relationship between humans and computers in which the computer, over time, would function less as a simple calculating tool for humans and more as a partner in handling complex phenomena via flexible programming and the increased roles of computers in fostering formulative thinking. He referred to this relationship using the term *symbiosis*. Specifically,

> In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking (p. 4).

However, and importantly, the computer would also

> …serve as a statistical-inference, decision-theory, or game-theory machine to make elementary evaluations of suggested courses of action whenever there is enough basis to support a formal statistical analysis. Finally, it will do as much diagnosis, pattern matching, and relevance recognizing as it profitably can, but it will accept a clearly secondary status in those areas (p. 7).

The vision for this relationship stemmed from Licklider's observation that a majority (85%) of his time was spent preparing to work (e.g., organizing, filing) rather than actually engaging in productive activity (e.g., theorizing). In a 1988 interview, Licklider elaborated,

> I tried to keep schedules and see how much time I spent doing what, and I was pretty much impressed with the notion that almost all the time I thought I was thinking and working, I was really just getting in the position to do something (p. 22).

However, before an enhanced relationship could develop between humans and computers, Licklider identified five areas in computing that needed improvement. He labeled these: *speed* *mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*.

Speed mismatch addressed the processing differences between humans and computers. Humans excel at complex, abstract thinking; computers excel in speed at calculating. Speed mismatch also addressed time-sharing: the need for computers to handle simultaneous users and to process multiple commands from concurrently running programs. In the late 1950s and early 1960s, time-sharing was a technology under development (Segaller, 1999). As with most new technologies, time-sharing had yet to reach its potential; it was costly, it was limited to expensive large-scale computers, and it was accessible only to a small sub-group of the population (mainly academic institutions, government agencies, and computer-focused private sector organizations). Despite these limitations, Licklider saw that improvements in time-sharing would be forthcoming to the point "10 or 15 years hence" when information storage and retrieval would be widely available via "thinking center[s]" to foster man-computer symbiosis. Furthermore, "The picture readily enlarges itself into a network of such centers, connected to one another by wide-band communication lines and to individual users by leased-wire services" (p. 7). Licklider's vision of networked computers was taking shape; accurately describing the future structure of the 1969 ARPAnet experiment.

Memory hardware limitations were also of concern, again largely because of the associated costs and limited storage capacities of that time (primarily in the low kilobyte range). Licklider identified two types of memory that would become increasingly important to the evolution of computers: indelible memory (closely paralleling today's RAM) and published memory (akin to ROM). Memory types, storage formats (e.g., magnetic tape, thin-film), selection circuitry, and the speed of these elements would have to improve dramatically before computers could create the "thinking centers" envisaged by Licklider.

In addition to memory hardware limitations, Licklider also saw the difficulty in accessing information stored in a computer, an issue of *memory organization*. He observed that information had to be quickly retrievable by name and by pattern searches in order for computers to enter into a symbiotic relationship with humans. Two areas of equal challenge regarding memory organization were identified as the storage procedure itself and pattern recognition within the stored data.

Regarding *the language problem*, Licklider wrote, “The basic dissimilarity between human languages and computer languages may be the most serious obstacle to true symbiosis” (p. 8). Although programming languages such as FORTRAN (known as assembly or compiling programs) helped to bridge the gap between human language systems and computer language systems, Licklider felt that a more fundamental difference in language structures had to be addressed. He observed that computer language, based on step-by-step instructions, specified courses of action while human language, based on incentives and motivations, specified goals. Licklider felt that computer language had to become more like human language—goal oriented—for symbiosis to occur. It is reasonable to assert here that this line of thinking likely related to his vision of computers eventually being accessible to a larger, less technically skilled population of users. From this perspective, the language barriers had to be minimized to foster effective interaction between computers and humans, with computers doing more of the adapting than their human counterparts.

Lastly, Licklider addressed the issue of *input/output equipment* limitations, identifying this as the least advanced area in computing. Specifically, computer displays—screens and their displays—and controls, mainly keyboards, did not compare with less technical mechanisms such as “the pencil and doodle pad or the chalk and blackboard” in terms of their usefulness and flexibility in the work and communication process (p. 9). Computer pens and touch pads were important elements to increasing interaction between humans and computers.

Summary of Main Ideas

The key ideas presented by Licklider in “Man-computer Symbiosis” form a hierarchical research agenda that can be divided into two basic categories: the general, overarching concept of human-computer symbiosis and the specific, subsumed technological advancements required in computing for symbiosis to occur. On a general level, Licklider’s idea for *symbiosis* proposed that computers move beyond functioning as “simple” calculating devices to handle more routine work functions such as filing and organizing information for easy retrieval, thus freeing humans to engage more frequently in higher level thinking. Additionally, computers should aid humans in complex thinking and decision-making through interactive programming capable of analyzing and presenting recommendations that humans could then accept, modify, or reject. Computers designed to accomplish such tasks would foster a symbiotic relationship between humans and computers to maximize the strengths of each: computers’ speed and accuracy matched with humans' ability for higher level, abstract thought. Additionally, and importantly, Licklider foresaw the widespread networking of computers to form "thinking centers" accessible to people via leased-line, broadband connections.

On a secondary level, Licklider identified five areas of computer technology that had to improve before a symbiotic relationship could develop and before large scale networking could be feasible. He divided his ideas for attaining symbiosis into five specific categories: *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. Although Licklider did not necessarily know how such improvements would come about in these five areas, he did know that they were key components to the feasibility and future success of human-computer symbiosis and an "intergalactic network" of computers.

To summarize, the ideas and the hierarchy in which Licklider expressed them were identified as:

Level I: Overarching idea presented in "Man-Computer Symbiosis"
Symbiosis

Level II: Subordinate ideas concerning the need for technological advancements in computing to address the following:
Speed mismatch
Memory hardware
Memory organization
The language problem
Input/output equipment

Licklider wrote the article in the fall of 1959, and Elkind received the completed manuscript on January 13, 1960.

> "It was…beyond expectations," says Elkind, who still marvels at what his mentor produced. Indeed, he says, when you look back at that paper from the perspective of today, knowing what happened later, you can see that it essentially laid out the vision and the agenda that would animate U.S. computer research for most of the next quarter century, and arguably down to the present day (Waldrop, 2001, p. 176).

However, it is important to note that Licklider did not limit his research agenda to print. Later, as the IPTO director at ARPA, Licklider funded a number of projects that advanced the specific areas that he outlined in "Man-Computer Symbiosis." These areas included, "operating systems, time-sharing systems and the like, graphics, data, databases, datatypes, languages, displays, controls, theory of algorithms," (Licklider, 1988, p. 54), and their funding helped to firmly establish and directly advance his research agenda for achieving symbiosis.

Interestingly, the American Heritage Dictionary defines *symbiosis* as "The relationship of two or more different organisms in a close association that may be but is not necessarily of benefit to each." By selecting the term *symbiosis* to describe this new relationship, it appears that Licklider intended to promote a mutually beneficial association between humans and computers. At the same time, he was aware of the possibility that such a balance might not be attained. In the event that an imbalance occurred, he hoped that humans would prevail.

Additional Writings

Although not the focus of this study, it is important to note that Licklider published subsequent work on the human-computer relationship that built upon the ideas presented in his 1960 article. In 1965, "Man-computer Partnership" was published in *International Science and Technology*. The article made additional mention of computer networking possibilities while reemphasizing the continued limitations of computers that were previously identified in "Man-computer Symbiosis." At the urging of Verner Clapp, president of the Council on Library Resources who commissioned the study, Licklider also published a book in 1965 entitled, *Libraries of the Future*. This publication examined the computer's role in automating the organization and retrieval of library data; an important task for meeting the information needs of a library and its patrons. Three years later in 1968, "The Computer as a Communication Device," coauthored with Bob Taylor of ARPA and published in *Science & Technology*, focused primarily on networking and the sharing of communication models via computers. Of the works mentioned, *Libraries of the Future* has been frequently cited over time, while the 1965 and 1968 articles have been cited less frequently in comparison.

Chapter Summary

This chapter provides the historical context for the study, beginning with a summary of literature citing the influential nature of Licklider and "Man-Computer Symbiosis." An overview follows that outlines Licklider's career and contributions in light of certain individuals who influenced his thinking, and it describes the larger social, political, and economic environment in which his work occurred. To address the first research question inquiring into the subject matter of "Man-Computer Symbiosis," a close reading identifies the general and specific ideas communicated by Licklider. The six ideas include: *symbiosis*, on a general level, and more specifically, *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. The second research question inquires into the spread and influence of "Man-Computer Symbiosis" within the research community. The influence network composed of citing articles and a subsequent analysis of the specific citations' content represent spread and influence. Diffusion of innovations and the agenda-setting function combine to provide the theoretical framework that guides these inquiries. Diffusion of innovations explains how innovations are communicated via certain channels among members of a social system over time. Agenda-setting explains how individuals and groups in positions of power are able to make topics salient in the minds of others. The following chapter details each perspective and its relevance to analyzing the influence network created by authors citing "Man-Computer Symbiosis."

CHAPTER THREE

THEORETICAL FRAMEWORK

Internet historians and others consider the publication of “Man-Computer Symbiosis” in 1960 to be a watershed event related to the Internet’s development (Gray, 2001; Hafner & Lyon, 1996; Packer & Jordan, 2001; Segaller, 1999; Taylor, 1989; Waldrop, 2001). Based on this perception this study further examines the spread and influence of the ideas contained in the article, focusing specifically on scholarly publications that cite “Man-Computer Symbiosis.” Hence, the role of scholarly publications in promoting the spread of ideas and an overview of the scholarly publication process are the opening topics for the chapter. The theoretical framework guiding this analysis is composed primarily of diffusion of innovations and secondarily of agenda-setting as it functions within the context of the diffusion process. Each theoretical perspective is presented in terms of its origins, typical uses within communication, strengths and limitations, and relevance to the questions asked in this study. The chapter concludes by linking the theoretical framework to the methods of data collection.

Scholarly Publication

The research community is a social system comprised of individuals who share values, norms, and codes of conduct (Cronin, 1984). Members of this particular social system are predominantly current or aspiring career (i.e., professional or private sector) researchers and academic researchers who communicate their research findings via “…a two-tier system, with informal networks [e.g., interpersonal conversations] being used to channel preliminary notifications of research findings, and the formal system [e.g., scholarly journals] being used as an archive of findings which have been vetted and approved by the scientific establishment” (p. 12). Publication formats in the formal system include: working papers, research reports, refereed and un-refereed conference papers, review articles, research monographs, refereed research articles, and textbooks (Thompson, 1995). This study focuses on the formal system used to channel research findings; more specifically, the study is limited to examining published research as indexed by the ISI (Institute for Scientific Information) citation indexes. These indexes primarily catalog refereed research articles, although the occasional text or conference proceeding may surface. For this reason, the remainder of the discussion is focused on scholarly journals, though much of this information is applicable to textbook and conference publishing practices.

At the most basic level, scholarly journals promote the sharing of ideas and results among researchers within and outside of a discipline, to foster the discussion and debate of these findings while simultaneously regulating controversy (Lindsey, 1978). More specifically, scholarly journals serve to 1) function as a communication channel for interested colleagues, 2) promote confidence in the quality of the research through the use of peer review, 3) provide researchers with a public forum for presenting original and valued thinking, and 4) acknowledge researchers' contributions (Cronin, 1984). A journal is typically overseen by an editor who functions as an initial gatekeeper, deciding if an article submitted for consideration is forwarded on for peer review, and, if so, to which reviewers in particular (Thompson, 1995). As such, editors, whose qualifications have been questioned at times, are highly influential in determining what research enters the published archive and what research does not (Paisley, 1989). In turn, these selections help to define research agendas within disciplines.

Peer review is an important and widely accepted component in the scholarly publication process because it is a primary mechanism by which experts in a field or sub-field assess the overall quality of a colleague's research to determine if the work is suitable for publication (Silverman, 1999). To offset biased decisions based on reviewers' favorable or unfavorable opinions about an author or an institutional affiliation, some scholarly publications conduct blind peer reviews of article submissions. In this process neither the submitting authors nor the reviewers know the others' identities. Ideally, then, it is the merit of the article that receives the attention of the reviewers and not the authors or their institutional affiliations. During the review process, the reviewers pay particular attention to the relevance and importance of the research topic, the appropriateness of the theoretical or conceptual frameworks used, the rigor of the methods and analyses conducted, the strength of the arguments put forth, and the quality of the writing. However, the blind review process is fallible. For example, in specialized sub-fields that contain a small number of researchers, it is possible for reviewers' to determine authors' identities based on the subject matter of the submissions. Consequently, review decisions may be influenced by this knowledge. Additionally, controversial topics and findings that do not conform to journal standards may be marginalized (i.e., rejected) by journal editors or during the peer review process (Lindsey, 1978). Generally, one of four possible decisions is reached by the reviewers: 1) the article is accepted in its current form, 2) the article is accepted with revisions specified, 3) revisions to the article are required and the article may be resubmitted for review, or 4) the article is rejected for publication.

Within the articles submitted for review, citation is a widely accepted and expected practice (Cronin, 1984). Citation is the process of formally acknowledging the use of others' work in one's own research to show "…explicit linkages between papers that have particular points in common" (Garfield, 1979). The citation process, in conjunction with the roles served by research associations and journals, also functions to limit plagiarism and, thus, to promote rigor and honesty in research by protecting the intellectual property rights of authors (Cronin, 1984). A more detailed discussion of the citation process is presented in Chapter Four.

Within the research community, publication in scholarly journals is expected of tenure-seeking and tenured faculty, particularly at research focused institutions (Silverman, 1999). Career researchers are also expected to publish their findings, but their publication outlets are not necessarily as limited as in the academy. Thus, with scholarly journals there is a dual motivation among academic authors to publish based on the ideal of contributing to the knowledge archive that is simultaneously coupled with a motivation to publish based on the pragmatic need to secure employment through the attainment and maintenance of tenure. One reason for the emphasis on publishing productivity in the academy is that it is much easier to document and quantify compared to the areas of teaching, service, and especially collegiality.

Not surprisingly, given the emphasis on publication, scholarly journals typically receive many more submissions than are accepted for publication, although this varies in extent by discipline (Lindsey, 1978). Esteemed journals within a discipline typically have high rates of rejection, which is generally taken to signify acceptance of only the highest quality research. For example, it is common knowledge in the communication discipline that the *Journal of Communication* has an approximate rejection rate of 80%, and it is viewed among communication scholars as a leading journal in the field based partly on this selectivity.

Consequently, a competitive element is added to the process in that *where* an author publishes is as important as what an author publishes (Lindsey, 1978, emphasis added). To conclude, the process may be summed up in the words of Terri Frongia (1995):

> *Scholarly publishing* may be defined as the end result of the full process of scholarly activity—query, investigation (research), cogitation, application, formulation/expression (writing), submission/review, and acceptance (publication)—which makes its full, "public" appearance in a scholarly forum (preferably a blind, peer-reviewed, readily recognized, academic or professional journal) (p. 219).

Thus, this overview provides insight into the procedures and motivations that helped to produce "Man-Computer Symbiosis" and the resulting set of citing articles examined in this study. The next section presents diffusion of innovations, the primary theoretical perspective that guides the inquiry concerning the spread of ideas via scholarly publication among members of the research community.

Diffusion of Innovations

Diffusion of innovations has a rich and varied history as a theoretical framework that examines the factors involved in the uptake of innovations among members of a social group. A 1943 study by Ryan and Gross, which examined the process by which Iowa farmers introduced to a new variety of hybrid seed corn decided whether or not to plant crops of the new seed, is considered by many to be the founding study for diffusion of innovations (Lowery & De Fleur, 1995; Rogers, 2003; Severin & Tankard, 1997). In the study, Ryan and Gross surveyed rural farmers in the central Iowa Corn Belt about their decisions related to adopting a new type of seed corn. The main conclusions of the study were: 1) a time lag existed between when potential adopters learned of the innovation and when the innovation was adopted, if it was adopted; 2) early adopters of the seed corn tended not to transition their crops completely over to the new seed corn, whereas later adopters were more likely to transition over completely after witnessing the successes of the early adopters; 3) hybrid seed salesmen were the dominant original source of information followed by neighbors; however, neighbors tended to be more influential in fostering the adoption process than were the salesmen; 4) although salesmen were initially the most influential source of information about the seed corn in the early stages of its diffusion, over time neighbors increasingly became more influential, and farm journals played only a minor role (Ryan & Gross, 1943).

Subsequent work by Everett Rogers during graduate school culminated in his 1962 publication entitled, *Diffusion of Innovations*. Rogers's research further refined the diffusion process, its theoretical underpinnings, and the terminology used to refer to the process by which people decide to accept or reject an innovation. Diffusion studies have since become numerous and ranging among a variety of disciplines. To illustrate its widespread use, Rogers (2003), who is largely credited with developing the theory, reported that in 1962 there were 405 diffusion related publications. As of 2003, he estimates the number of diffusion studies to be greater than 5200.

Diffusion Defined

In general, diffusion of innovations examines "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, p. 5). The aforementioned "process" is known as diffusion. Rogers divides the process into four components: 1) the innovation, 2) communication channels, 3) time, and 4) the social system. Each segment is described briefly.

Although the term innovation may evoke images of specific technologies such as computers and electron microscopes, the term covers a much broader range. An innovation is defined as "an idea, practice, or object that is *perceived* as new by an individual or other unit of adoption" (p. 11, emphasis added). An innovation possesses certain attributes that either contribute to or inhibit its adoption.

In the context of diffusion, communication is of a special type in that the messages focus on new ideas. The channels by which the innovation is communicated are broadly divided into mass and interpersonal channels. Mass communication channels (e.g., print, television, radio, and some elements of the Internet, such as the Web) are typically the most rapid and efficient vehicles for alerting potential adopters about an innovation's existence. Interpersonal channels (e.g., face-to-face conversations and some element of the Internet, such as email) excel at persuading individuals or groups to adopt, particularly if users of this channel are similar in education, socio-economic standing, etc. Adoption refers to a decision by an individual or group to incorporate an innovation into routine practices.

Time is a critical element in the diffusion process because not all members of a social system spontaneously and completely adopt innovations upon their release (indeed, some members may never adopt); rather, the uptake of an innovation varies, for example, in terms of its attributes and the characteristics of the potential adopters. The typical diffusion or rate of adoption pattern for an innovation follows an S-curve shape. This shape can be divided into three phases. The first phase of adoption is relatively flat and represents an initial slow uptake upon the innovation's introduction. The second phase depicts a noticeable rise in adoption relative to the first phase and signals widespread acknowledgement (via adoption) of an innovation's value and use. The point at which enough members of the social system adopt an innovation and its rate of adoption becomes self-sustaining is referred to as reaching "critical mass" (Rogers, 2003). A leveling off or persistent decline in adoption characterizes the third phase to signal that an innovation has saturated the social system, exhausting the supply of potential adopters.

The social system is comprised of interrelated "…individuals, informal groups, organizations, and/or subsystems" involved in joint problem solving to achieve a specified outcome (Roger, 2003, p. 23). Characteristics of a social system affect the diffusion of an innovation. Some contributing factors include: the structure or organization of the system (e.g., hierarchical versus flat), system norms (e.g., formal and informal codes of conduct), the presence of opinion leaders and change agents, and the types of innovation decisions that occur within the system.

Detailing the Diffusion Process

Typically, an innovation passes through six stages: 1) identification of a need or problem, 2) application of basic and applied research to assess need and feasibility, 3) development, 4) commercialization, 5) diffusion and adoption, and 6) consequences (Rogers, 2003). The diffusion process focuses primarily on step five, the point at which potential adopters become aware of an innovation's existence. According to diffusion, both the innovation and the potential adopters of the innovation possess certain characteristics that play key roles in the diffusion/adoption process. Regarding the innovation, five characteristics play important roles in the process: 1) relative advantage, 2) compatibility, 3) complexity, 4) trialability, and 5) observability. Relative advantage refers to the degree to which the innovation is superior to what precedes it. The higher the relative advantage, the more likely adoption will occur. Compatibility refers to the degree to which the innovation fits in with current practices, norms, etc. The higher the compatibility, the more likely adoption will occur. Complexity refers to the degree to which the innovation is easy to understand and use. The lower the complexity, the more likely adoption will occur. Triability refers to the degree to which the innovation can be experimented with on a limited basis. The higher the triability, the more likely adoption will occur. Lastly, observability refers to the degree to which the results/effects of the innovation can be observed. The higher the observability, the more likely adoption will occur.

Potential adopters—individuals or groups deciding whether or not to accept the innovation—are categorized as innovators, early adopters, early majority, late majority or laggards. This classification is a function of when an individual adopts an innovation in relation to those who already have. As one moves from the innovator category to the laggard category the following patterns tend to occur: 1) openness to experimenting with innovations decreases, 2) willingness to adopt an innovation decreases, 3) educational and income levels decrease. The perceived attributes of an innovation that potentially affect an adopter's decision about it include its relative advantage, compatibility, complexity, trialability, and observability. These factors, however, are only building blocks for how the diffusion process functions within and among networks of people.

The preceding discussion concerning innovation and adopter characteristics is based largely on the ability of the individual to have complete control or the majority of control in the adoption decision process. However, members of a group (e.g., a professional organization, workplace setting) do not necessarily have a high degree of choice regarding an innovation. At the group level, the decision to adopt an innovation typically occurs in one of three ways: 1) optional decision, 2) collective decision, and 3) authority decision. Optional decisions allow the individual to decide whether or not to adopt independently of the group. Collective decisions are based on group consensus about whether or not to adopt. Authority decisions occur when relatively few members of the group who possess power, status, and/or technical expertise make the adoption decision for all members.

Within an organization, the innovation process is divided into two main general phases: 1) initiation and 2) implementation. These two phases are further divided into five stages: 1) agenda-setting, 2) matching, 3) redefining/restructuring, 4) clarifying, and 5) routinizing. The initiation phase contains the agenda-setting and matching stages. The implementation phase contains the three remaining stages. The five stages are described briefly. The agenda-setting stage is the point at which recognition of organizational problems prompt a need for innovation. The matching stage is the point at which the organization's agenda for solving a problem is aligned with an innovation. The redefining/restructuring stage signals the modification or reinvention of an innovation to meet an organization's needs as well as the modification of organizational structures to accommodate better the innovation. The clarifying stage occurs when the relationship between the organization and the innovation is more clearly defined. Lastly, the routinizing stage is the point at which the innovation becomes a regular part of the organization and loses its identity as being a new element.

Regardless of whether the adoption decision takes place at the individual or group level, the basic process in the diffusion of an innovation occurs in five stages: 1) knowledge, 2) persuasion, 3) decision, 4) implementation, and 5) confirmation. Knowledge about the innovation must occur before an adoption decision is possible. Persuasion is the stage where the individual or group weighs the advantages and disadvantages of the innovation and where change agents and opinion leaders can play key roles. The decision stage involves the act of adopting or rejecting the innovation. Implementation occurs when the adopted innovation is incorporated into an existing framework. Lastly, confirmation is the stage at which the individual or group reflects on the decision to adopt and looks to others for support in having made the decision. It is in this last stage that discontinuance—the decision to disadopt the innovation—is likely to occur, if at all.

Diffusion Networks

Whether a decision to adopt occurs on the individual or the group level, people rarely, if at all, live in isolation. Instead, we are part of various social networks that link us with family, friends, colleagues, and others to greater and lesser degrees. The diffusion of an innovation is dependent, in part, on how information about the innovation is communicated through these networks to potential adopters. The two basic diffusion networks are termed *homophilous* and *heterophilous* (Rogers, 2003). Homophilous networks include members who are similar with regard to certain attributes such as education, occupation, income, beliefs, and so on. Heterophilous networks involve members who are dissimilar with regard to these attributes. Homophilous networks arise frequently because they tend to foster more effective communication than heterophilous networks. Diffusion of an innovation tends to accelerate in homophilous networks due to the similarities of the members; however, the spread of the innovation is usually limited to the members of that network. In the case of heterophilous networks, diffusion tends to be slow, but, if successful, its spread may be more far reaching than in homophilous networks.

Within networks, certain individual types frequently play key roles in the diffusion of an innovation. These individuals include opinion leaders and change agents (Rogers, 2003). Opinion leaders generally have strong ties to the members of a network, conform most to system norms yet are generally more innovative (but not necessarily innovators) than the other members, and are viewed as credible sources of information. Given their status within a network, opinion leaders are potentially well positioned to set agendas. In instances where a setting favors change, opinion leaders may be innovators. When change is not favored, however, opinion leaders are not likely to be especially innovative or to be innovators. Change agents, frequently acting on behalf of a change agency, are those individuals who seek to create change in a system but who lack the connection to the system's members that an opinion leader has. Change agents necessarily work through opinion leaders when attempting to diffuse an innovation into a system.

Questions Asked by Diffusion

To summarize, the diffusion perspective asks four basic questions related to the spread of an innovation among potential adopters. First, with respect to the innovation itself, diffusion inquires into the attributes of the idea, object, or practice as these relate to the characteristics of the potential adopters. Second, diffusion inquires into the communication channels and the characteristics of the messages used to provide information about the innovation. Third, diffusion examines the component of time as it relates to the spread of an innovation in a social system. Finally, diffusion inquires into the characteristics of the social system in which the potential adopters are members.

Strengths of Diffusion

The three main strengths of diffusion of innovations, as outlined by Rogers (2003), are easily tied into three primary criteria used to evaluate the usefulness of a theory: generality, explanatory and predictive ability, and parsimony. Since its early origins in the 1943 Ryan and Gross study of hybrid seed corn adoption among Iowa farmers, the diffusion model has been applied to numerous settings across numerous disciplines. As of his 2003 writing, Rogers estimated that more than 5200 studies have been conducted using diffusion of innovations as a theoretical framework throughout the humanities, social sciences, and the sciences. One test of a theory's utility rests on its ability to account for a number of situations in a variety of settings and, in this regard, diffusion is quite strong.

Second, diffusion of innovations is good at linking research-based data with potential adopters in a knowledge-utilization process to help explain the attitudes as well as the behaviors of these individuals. This strength has been used, for example, in many marketing research applications to predict the likely uptake of an innovation. Consultants also use the diffusion framework to assist organizations attempting to introduce innovations into the workplace.

Lastly, diffusion of innovations allows researchers to move beyond the level of their data to link the findings to more abstract concepts such as innovation attributes and adopter characteristics. The ability to link concrete results to general explanatory concepts demonstrates the theory's parsimony. The theory is parsimonious because it is able to address a complex subject via relatively few precise definitions and categories to consistently illustrate the diffusion process for numerous innovations in a variety of settings.

In addition to these three areas identified by Rogers, diffusion of innovations is strong in its ability to address macro and micro level elements that contribute to the spread of an innovation. At the macro level, diffusion of innovations provides insight into the roles of time, communication channels, social systems, and diffusion networks in the diffusion process. At the micro level, diffusion of innovations offers insight into the roles played by innovation attributes, potential adopter characteristics, opinion leaders, and change agents in the diffusion process.

Limitations of Diffusion

Although diffusion of innovations is a very useful theory, it has four primary limitations, each of which is discussed briefly: a pro-innovation bias, an individual-blame bias, a reliance on recall data, and a tendency to increase socio-economic gaps (Rogers, 2003). The pro-innovation bias is the assumption that all members of a system should adopt the innovation, adoption should occur rapidly, and the innovation should neither be rejected, discontinued or reinvented (i.e., modified from its original form). This bias predisposes researchers to focus only on successful diffusions. The consequence of this particular bias is a resulting limited knowledge about the failure, rejection, discontinuance, and reinvention of innovations. This bias overlooks the reality that many more innovations fail than succeed. It also presupposes that only the best innovations succeed and tends to ignore the effects of social, political, and economic practices on the diffusion process. A consequence of this oversight is that innovation is often viewed historically as a linear function with consecutive innovations building successfully upon previous successful innovations, when in fact the innovation process is much less straightforward and more fraught with failure (Braun, 1992). The pro-innovation bias also tends to neglect the importance of anti-diffusion initiatives, such as alcohol and drug cessation campaigns that aim to reduce rather than increase the uptake of certain products or lifestyles by potential adopters. One reason behind this particular bias stems, in part, from the initial Ryan and Gross (1943) study that examined the very successful diffusion of hybrid seed corn, which implicitly created an expectation that future research focus on successful diffusions. Additionally, diffusion research funded by change agencies tends to be biased in favor of the innovation given the sponsor of the research. As a result, researchers tend to perceive widely and rapidly diffused innovations as noteworthy and of greater interest than lesser successful or unsuccessful diffusions.

The individual-blame bias refers to diffusion researchers' tendency to blame the individual rather than the system in which the individual resides for adoption failures. The researcher looks within the system for problems rather than at the system as a whole when attempting to explain why a certain innovation did not diffuse successfully. One reason for this bias is that most diffusion studies use the individual as the unit of analysis and neglect examining the larger social system in which the individual resides. Another reason stems from the tendency of change agencies to fund diffusion research—naturally, the agency has a tendency to take an "us vs. them" approach and to pass this bias on to the researcher. Lastly, diffusion research tends to be audience-focused rather than source-focused, thus increasing the likelihood of reaching an individual-blame conclusion.

Another limitation of diffusion research is the heavy reliance upon the recall of participants, which weakens the validity of the data collected given that recall can be affected by such factors as: 1) the salience of the innovation to the individual, 2) the time period, in terms of length and distance, over which the individual is asked to recall his or her adoption decisions and, 3) differences in education, memory ability, etc. among those surveyed. Tied into this limitation is the heavy reliance on single-point-in-time surveys for data collection. Diffusion is a process that occurs over time and it is unrealistic to think that a one-time administration of a survey can capture this dynamic element of the process.

A fourth limitation of diffusion of innovations is that it tends to widen socioeconomic gaps, particularly in developing countries and especially with regard to technological innovations (e.g., computers). Diffusion of innovations is based largely on a Western mindset (e.g., democracy, capitalism) and asks questions primarily related to technological advancement and economic profitability and growth (Arnould, 1989; Hedley, 1998). The success or failure of an innovation is measured largely in terms of its economic success (i.e., monetary profitability), which tends to neglect other less tangible but still valid measures of success, such as quality of life improvements (Braun, 1992). In part, the problem with this bias lies in an assumption that individuals in developing nations have or desire the same or similar freedoms of choice in adopting an innovation.

Additionally, innovations themselves carry underlying economic, political, and social values and norms—referred to as the "technical code" (Flanagin, Marinola & Fetzer, 2000)—that may continue to foster gaps in a society as these underlying codes do not carry the same weight and meaning across social systems. For example, the Internet is largely a U.S.-based creation and functions, in part, on the premise that free access to information is a beneficial characteristic of the technology. However, in China, security of information is valued more than free access to information, thus the Internet in its current form functions in a manner that is counterproductive to the political viewpoint of the Chinese government. Thus, depending on one's perspective, the diffusion of the Internet in China may be viewed as a disruptive or liberating event. Diffusion of innovations does not examine the motives behind introducing an innovation (e.g., for the public good, for profit) or, again, the consequences (e.g., shifts in citizen migration patterns, employment opportunities, disruptions in political systems).

Finally, certain terms and definitions within diffusion of innovations need re-examination. Specifically, the terms "laggard" and "late majority" promote the pro-innovation bias from within the theory. The negative connotation associated with the terms "laggard" and "late" makes it appear that individuals who do not readily adopt, or at least who do not adopt with the early majority, are somehow flawed and of less value. In fact, these individuals potentially serve an important function by acting as the collective brake to slow down the spread of what may not necessarily be a beneficial innovation (Fidler, 1997). Additionally, the theory needs to take into account the emergence of the Internet and its subsequent blurring of traditionally separate communication channels by which innovations may be communicated, although this appears to be taking place in the latest edition of Rogers (2003).

In concluding this section, proposed solutions for addressing these limitations are based on suggestions by Rogers (2003), who, to his credit, provides a thorough overview of diffusion's weaknesses. For the pro-innovation bias, researchers must accept that some people will reject, discontinue, or reinvent an innovation for reasons that seem justified from their perspectives. Rather than ignore these individuals, diffusion research can be greatly enhanced by examining their motives. Regarding the individual-blame bias, researchers must work to keep an open mind about the reasons behind diffusion failures and look to both the individual and the system for explanations. The recall problem can be minimized by combining data collection techniques, such as document analysis with in-depth interviews to improve the validity of the data. Finally, the inequality bias can be reduced by shifting the focus of diffusion studies from a Western-oriented frame of reference to one that examines questions of motives, consequences, and that asks the "Why?" behind differences in diffusion patterns between groups (Braun, 1992); a good opportunity to include qualitative research approaches.

Primary Applications of Diffusion in Communication Research

An examination of the communication literature indicates that diffusion studies center on three main topics, the majority of which are related to the mass media: the diffusion of news stories (e.g., Bantz, Petronio, & Rarick, 1983; De Fleur, 1988; Haraldsen, Broddason, Hedinsson, Kalkkinen, Kalkkinen & Nordahl, 1987; Kubey & Peluso, 1990), the diffusion of health messages (e.g., Meyer, Johnson, & Ethington, 1997; Placek, 1974-75; Pohl & Freimuth, 1983; Svenkerud, Singhal, & Papa, 1998), and the diffusion of new technologies (e.g., D'Alessio, 2000; Garrison, 2000; Leung & Wei, 1999). These groupings were obtained via a keyword search conducted on the term *diffusion* in the ComAbstracts database (Communication Institute for Online Scholarship, n.d.), covering the years 1966-2002 for over fifty communication journals. Of the 81 articles produced by this keyword search, approximately 47% focus on the diffusion of news, 23% focus on the diffusion of technologies, and 9% focus on the diffusion of health messages. The remaining 21% of the articles address policymaking, theoretical, and statistical topics related to diffusion research. Within these three main categories of diffusion research, the majority of studies examine adopter traits, characteristics of the innovation, and/or communication channels as outlined by Rogers (2003).

Using Diffusion to Trace the Spread of Ideas

Two approaches are taken to address the usefulness of diffusion of innovations for tracing the spread of ideas over time. First, an overview of research using diffusion to trace the spread of idea is presented. Second, the relevance of the diffusion perspective to this study is outlined. At this point, it is useful to restate the definition of diffusion: the process by which an innovation is communicated via certain channels over time among members of a social system.

Related Diffusion Research

As mentioned previously, the majority of diffusion studies within the communication discipline tend to focus on the spread of news stories, health messages, and the adoption of new technologies. A few studies directly or indirectly apply or discuss the usefulness of applying diffusion to the spread of ideas in the research community (Aikat, 2001; Beniger, 1988; Borgman, 1989; Paisley, 1989; Rogers & Dearing, 1993). This is not necessarily a negative trend; rather, it suggests that the application of diffusion, particularly within the communication discipline, is somewhat narrow in light of its broad applicability. In this sense, this study assists similar studies to expand the application of diffusion within the discipline.

A 2001 published study by Debashis Aikat most closely approximates the substantive and theoretical goals of this study with respect to applying diffusion of innovations. Combining diffusion of innovations and actor-network theory, Aikat traced the spread and influence of ideas for five prominent computing pioneers between the years 1833 - 1945. The five individuals included: Charles Babbage, George Boole, Herman Hollerith, Alan Turing, and Vannevar Bush. Aikat conducted an interpretive historical analysis by qualitatively analyzing the primary texts of these individuals along with other related texts to draw conclusions about the spread and influence of each individual's ideas. In applying diffusion of innovations to explain the spread of ideas contained within the documents examined, Aikat emphasized the role of the change agent with respect to Babbage, reinvention in the case of Turing, and the lead user (i.e., innovator) adopter category as it applied to Bush. Based on the analysis, the author summarized three main lessons essential to understanding future developments in media technologies: 1) innovations are products of the needs and effects of the times, 2) the printed word is a powerful means for diffusing innovations, and 3) innovators and dominant technologies shape emerging media. Although an interesting study, it is limited in that it focuses primarily on the producers of the texts. This focus limits claims about the influence of the writings because it does not investigate the recipients of the messages. The author readily acknowledges the importance of future research examining the evolution of computing after 1945 and the need to assess public perceptions "…as reported in specialised engineering and scientific journals, and popular media" (p. 75).

This study expands upon Aikat's research by applying other elements of the diffusion of innovations perspective to include the characteristics of the diffusion network, the dually held role of opinion leader and change agent by an individual, the role of agenda-setting in the initiation phase of an innovation, and a closer examination of time's role in the diffusion process. Additionally, this study analyzes a 1960-2001 timeframe for a specific publication, which expands upon the timeframe used by Aikat. Lastly, this study examines both the published source of an idea (in this case, "Man-Computer Symbiosis") and the recipients of the idea (in this case, the influence network as represented by citations to Licklider and analysis of the citations' content).

Relevance of Diffusion to the Study

Diffusion of innovations is particularly relevant to this study given the theory's focus on the process by which innovations are communicated via certain channels to members of a social system over time. A goal of this study is to trace the spread of Licklider's ideas, as expressed in "Man-Computer Symbiosis," among members of the research community over a 40-year timeframe. In this study, the innovation is a combination of Licklider's general idea for *symbiosis* coupled with a more detailed discussion of required technological improvements in the areas he labeled: *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. One mass communication channel that Licklider used to communicate his new vision for computing was print media, specifically a scientific journal. The year was 1960 and the article was published in the *IRE Transactions on Human Factors in Electronics*. The social system into which the article was introduced primarily includes career and academic researchers. The timeframe for the study covers the years 1960-2001. Importantly, this study focuses on the broad definition of diffusion. Within this broad definition, the study examines the roles played by diffusion networks, time, agenda-setting in the initiation phase, and opinion leaders and change agents to the spread and influence of the ideas contained in "Man-Computer Symbiosis." It does not emphasize, for example, the specific attributes of the innovation, adopter categories, or the types of group adoption decisions.

The explanatory and predictive abilities of diffusion of innovations are widely applied to areas such as product marketing and public health campaigns (Rogers, 2003), but diffusion of innovations is not limited to these settings. It is not a goal of this study to predict; however, the characteristics of the diffusion network (i.e., homophilous or heterophilous) as represented by the network of articles containing citations to "Man-Computer Symbiosis" may be explained by the theory. The theory is also useful for explaining Licklider's dual role as an opinion leader and change agent within the research community, his role in setting a research agenda in the innovation's initiation phase, and for revealing the pattern of the article's adoption over time.

Relating the general limitations of diffusion of innovations—pro-innovation bias, individual blame bias, inequality bias, and recall bias—to this study, the following can be said: These limitations do not directly apply to this study's use of the theory. One might argue that selecting to study the ideas of an Internet pioneer suggests a pro-innovation bias given the relatively widespread and rapid diffusion of the technology over the past decade, particularly in the United States. However, the goal of the study is not to promote worldwide diffusion of the Internet; rather, it is a look back at one aspect concerning the spread of early ideas for advancing computer technology such that several decades later we now have a functioning, almost world-wide, network of computers.

Histories written about the Internet have done an excellent job identifying a number of key players involved in the Internet's development using interviews and other primary source materials. However, one limitation of this approach is also identified as a limitation of most diffusion research: the reliance on recall data generated by surveys and interviews. For example, Larry Roberts, a key contributor to the Internet's development, acknowledged that his recollections about the Internet's beginnings may have inadvertently omitted key players or incorrectly reported their roles (Roberts, 1989). This study examines archival material in the form of the scholarly publications, an approach suggested by Rogers (2003) to offset the recall limitation in diffusion research generally. Investigating the published record does not imply that the study will provide *the* answer to the extent of Licklider's influence on interactive computing and the Internet's development. It will, however, allow us to examine the spread and influence of his early ideas for symbiosis and networked computing from a different perspective that can then be compared to other accounts about his role.

The individual-blame and the inequality biases associated with diffusion of innovations do not pertain to this study. Clearly, however, the Internet has not diffused equally throughout the world or even within the United States, hence the concern of many about the Digital Divide. This gap in access is related to the inequality bias—that technologies tend to diffuse in ways that increase rather than reduce social imbalances, an area not covered in this study. Research tends to focus on the individuals who lag behind in adopting the Internet rather than the social systems in which the individuals reside when looking for ways to solve the information gap. Focus on the individual rather than the social system ties into the individual-blame bias; this study focuses on the social system. Certainly, Licklider knew there would be consequences to increasing the role of computers in our lives and in networking computers. After all, his military-based research on the SAGE system focused on using computers to defend U.S. skies from aerial attacks. Yet, he still saw enough potential for good in his idea to share it with others, and that venture deserves a closer look.

Diffusion: Theory or Model?

Before concluding the discussion on diffusion it should be acknowledged briefly that some researchers debate whether diffusion is a theory or a model describing a process. To illustrate, communication scholars Lowery & DeFleur (1995) and Severin & Tankard (1997) include diffusion of innovations as a theory in their course texts summarizing major theories in the discipline; however, Griffin (2003) does not, preferring to list diffusion of innovations as a process within the broad context of media effects that can then be analyzed using specific theories such as the two-step flow of communication and agenda-setting. To argue one way or another on this issue is ultimately beyond the scope of this study. The selection of diffusion of innovations as a guiding theoretical framework for this study is based on its wide-ranging ability to explain the factors involved in the spread of an innovation among individuals over time, a primary goal of the study.

Agenda-Setting

According to Dearing and Rogers (1996), “Every social system must have an agenda if it is to prioritize the problems facing it, so that it can decide where to start work. Such prioritization is necessary for a community and for a society” (p. 1). In general, agenda-setting is the process by which particular issues or topics are made the focus of attention among members of a social system by an individual or group of individuals who are in the position (e.g., financially, by reputation, access to communication channels) to disseminate the messages. The origin of a systematic investigation of the agenda-setting function is credited to the 1972 McCombs and Shaw study of 100 undecided voters in Chapel Hill, North Carolina. Participants were asked to list "the major problems [in the country] as they saw them" (p. 178). Responses from the interviews were compared with the results from content analyses of major newspapers, news magazines, and television news broadcasts to reveal an extremely high correlation (in the .9+ range) between participants' concerns about major issues facing the country and those presented in the media. Thus, agenda-setting is founded on a history of investigating the effects of mass media on shaping public opinion.

Agenda-Setting Defined and Summarized

As defined by Dearing and Rogers (1996), "An agenda is a set of issues that are communicated in a hierarchy of importance at a point in time" (p. 2). Issues typically identify social problems that may or may not involve conflicting viewpoints on how best to address them (e.g., homelessness, drug abuse, environmental protection). Agenda-setting is traditionally defined as the process by which issue proponents compete to gain recognition by media professionals, the public, and policy makers. The ability to gain attention from the media, the public, or policy makers signifies the power held by individuals and groups to influence the decision process related to particular topics. In this process, certain topics or issues receive attention while others do not.

Initially, research claimed that the agenda-setting function did not tell people how to perceive an issue or topic; rather, it had the effect of making certain items salient in the minds of listeners, readers, and viewers of media. Agenda-setting developed at a time when communication researchers were generally dissatisfied with a limited effects model of media influence. The limited effects model ran counter to early communication research that promoted a "hypodermic needle" model of mass effects. Agenda-setting occupied a middle ground between limited and powerful effects models. However, over time, subsequent agenda-setting research modified this initial statement to indicate that the framing of an agenda can affect not only *what* people think about but also *how* they think about the topics presented by the media (Dearing & Rogers, 1996; Kosicki, 1993; McCombs & Shaw, 1993), thus producing a shift toward stronger effects than originally claimed.

Currently, agenda-setting research focuses on three broad areas of the process: 1) the media agenda, 2) the public agenda, and 3) the policy agenda (Dearing & Rogers, 1996). The media agenda research is governed by the overarching questions, "What puts an issue on the media agenda?" (p. 24) and "Who sets the media agenda?" (McCombs, 1993, p. 60). In addition to identifying the most prevalent issues covered in the media, this question deals with factors potentially affecting those items that receive media coverage and those that do not, such as reporter bias, media ownership, the role of editors, and the sources of information. The media agenda is usually measured via content analyses, often in the form of story column inches and keyword frequencies.

The public agenda research is guided by an interest in the prioritization of main issues by the general public at a certain point in time (Dearing & Rogers, 1996). Studies in this area also examine the increase and decrease in popularity of one or a few issues across time. The public agenda is frequently measured by surveys or opinion polls that ask about a respondent's attitude toward a specific issue or a broader agenda. These questions typically take the form of "How do you feel about X?" or "What do you think is the most important problem [or problems] facing this country today?" In some studies, experiments have been used to measure the public agenda and have demonstrated the implied cause-effect relationship between the media and the public. In general, of the three areas investigated in the agenda-setting process, the public agenda has been the most thoroughly researched.

Lastly, the policy agenda examines how issues become part of the policy-level agenda to potentially affect government policies, laws, and so forth addressing or resolving social problems. This area of research investigates, for example, the influence of public and media agendas on shaping the policy agenda, the role of policymakers in functioning as gatekeepers when determining which topics are most important to address, and policymakers' use of media outlets to serve their interests. Unlike the media and public agendas, a dominant method for measuring the policy agenda is less clear. Methods used so far include: field experiments, historical analysis, policy analysis, and case studies. Of the three areas, the policy agenda is the least investigated by communication researchers (Dearing & Rogers, 1996).

The Use of Agenda-Setting in Communication Research

The majority of studies applying agenda-setting within communication do so in relation to mass media, particularly the news media. In part, this trend appears to be due to the precedent set forth in the McCombs and Shaw (1972) study, which specifically examined the influence of mass media on undecided voters. A keyword search conducted in ComAbstracts (Communication Institute for Online Scholarship, n.d.) on the term *agenda-setting* produced 65 articles published on the topic during the years 1966-2002. Based on a cursory examination of the resulting 65 articles, approximately 69% of the articles focused on agenda-setting in the mass media (e.g., television, news reporting), 19% focused on theoretical and/or statistical aspects of agenda-setting, and 12% focused on a mix of other topics. As with the diffusion overview, the infrequent application of agenda-setting within the context of this study's setting does not necessarily indicate inappropriate use of the theory. Rather, as this study demonstrates, using the agenda-setting function to analyze the spread of ideas may expand the practical utility of the perspective and also expand its application within the communication discipline. This topic is discussed in more detail after first reviewing the strengths and limitations of agenda-setting.

Strengths of Agenda-Setting

McCombs and Shaw (1993) identify three strengths of agenda-setting based on a twenty-five year overview of trends in the communication research literature. The first strength of the theory is illustrated by its growth over time, which indicates the theory's generality and practicality. A Rogers and Dearing (1993) study that examined 223 multidisciplinary publications using agenda-setting supports this observation. The second strength listed by McCombs and Shaw is that agenda-setting functions well to integrate sub-fields of communication research into a more coherent body of research. This has been accomplished through, for example, the expansion of the theory over time to include contingent conditions that expand or limit media agenda-setting, to investigate the theory's applicability in new settings, and to conduct more research focusing on the area of the media agenda and how it is set. The third strength of agenda-setting lies in its continued ability to produce new areas of research and research problems across multiple communication settings, a goal of this study. In summarizing trends in agenda-setting research, the authors conclude, "The marketplace [of ideas within the communication discipline] has not yet settled on the most appropriate domains for agenda-setting theory" (p. 65). Thus the applicability of agenda-setting is more wide-ranging than our research has demonstrated so far.

From the perspective of this researcher, another strength of the agenda-setting process lies in its ability to reveal the influence of both large and small power structures that work to set agendas in society, whether these power structures exist within large international media corporations or small research communities. Agenda-setting allows us to examine the individuals and groups that function directly and/or behind the scenes to promote certain ideas and the frames within which these ideas are presented. In this way, agenda-setting can reveal some of the formal and informal links between the promoters of ideas and the receivers of the ideas.

Limitations of Agenda-Setting

Kosicki (1993) presents a comprehensive overview on the limitations of agenda-setting, the majority of which concern its application by communication researchers. One limitation of agenda-setting is the tendency for researchers to focus on one of the three aspects—media, public, and policy agendas—of the process rather than studying the process as a whole. As Dearing and Rogers point out (1996), the majority of agenda-setting research in communication has focused on the public agenda. Although the media agenda is receiving more research attention than previously, it was originally taken as a given by researchers and subsequently not considered a topic requiring examination. By comparison, the policy agenda receives scant attention in communication research, though it tends to receive the focus of sociologists. Studies examining two or three of these areas, though understandably more complicated, stand to produce more robust findings about the agenda-setting process.

Similar to diffusion of innovations, a second limitation of agenda-setting concerns the question of whether it is a theory or a model describing a process. Kosicki (1993) claims that agenda-setting is best described as a model of media effects. Interestingly, some communication texts introducing future scholars and professionals to the discipline present agenda-setting as a theory (e.g., Griffin, 2003; Severin & Tankard, 1997) while others present it as a process or a hypothesis (Dearing & Rogers, 1996; Lowery & De Fleur, 1995). As with diffusion of innovations, the debate about agenda-setting as theory or model is beyond the scope of this study. However, an unintended consequence of such a debate is that focus is shifted from the applicability of agenda-setting to explain a wide range of phenomena to a focus on "correctly" classifying it.

A third limitation of agenda-setting concerns the superficial treatment of content in studies examining the public agenda (Kosicki, 1993). In part, this is due to the founding McCombs and Shaw (1972) study, which grouped respondents' concerns into broad, abstract categories, such as environment, economy, trustworthiness of government. Grouping into broad categories tends to exclude analyzing the specifics of the issues, which may vary across respondents (e.g., specific environmental concerns, such as overflowing landfills or emission controls). However, knowledge about these specifics would provide a clearer picture of how issues evolve over time when media portrayal is taken into account.

A fourth limitation of agenda-setting is that by definition it hypothesizes a causal relationship between the media and the public; specifically, that media affect public opinion. However, the methods used to ascertain this relationship, content analysis and surveys, are weaker at determining causality than are, for example, experiments. This leads to the question of whether media are setting agendas or, instead, reflecting agendas that they detect in the general public. Studies responding to this question that have used experimental procedures have found support for the hypothesized relationship (Dearing & Rogers, 1996).

Related Agenda-Setting Research

Within communication scholarship, a study by Rogers & Dearing (1993) is very similar to this study in terms of its goals and methods. In brief, the Rogers & Dearing study investigated "the complex intellectual history of agenda-setting research by identifying over-time patterns of (a) publications and (b) bibliographic citations" (p. 69). Although it was not explicitly stated, the authors examined the diffusion of agenda-setting research over a seventy-year period, from 1922 to 1992. Specifically, they examined articles that addressed at least one of the agenda areas: media, public, and policy. One goal of the study was to trace the paradigmatic shift in communication research from a limited effects model of mass media to the moderate effects model proposed by agenda-setting. The authors determined that a lag time generally exists between the time a research study is published and when it is first cited. The lag time can range from one to several years. Although the 223 articles examined were multidisciplinary, the majority of agenda-setting research was published in communication journals. Of the articles examined, the 1972 McCombs and Shaw study was the most frequently cited article, which supports the general perception among communication scholars that it was an early founding study that formalized the agenda-setting process and signaled a shift to a moderate effects model.

The Rogers and Dearing study is similar to this study in that both trace intellectual histories that may reveal paradigmatic shifts in thinking. In this study, Licklider's proposal for redefining the human-computer relationship signaled a shift in how the role of computers had been typically defined in his day—large, standalone calculators versus interactive communication and thinking tools. Both studies use quantitative methods to examine intellectual histories in place of more interpretive approaches. This study differs from the Rogers and Dearing study in that it combines citation analysis with quantitative content analysis. The Rogers and Dearing study examined citation patterns across a series of agenda-setting research articles, whereas this study uses citation analysis to identify the network of researchers citing ideas in a source article, "Man-Computer Symbiosis." In this sense, this study has a narrower focus than the agenda-setting study.

Relevance of Agenda-Setting to the Study

As noted earlier, within the communication discipline agenda-setting is frequently applied to study news media and the formation of public opinion. The agenda-setting process, however, occurs in other settings including organizational and interpersonal networks, and it plays a role in the diffusion of innovations (Rogers, 2003). Within organizations, agenda-setting occurs when a problem is identified and an innovation is sought to resolve the problem. According to Rogers, "The agenda-setting process is continuously under way in every system, determining what the system will work on first, next, and so forth" (p. 422) to create a hierarchy of attention among members of an organization.

In the previous diffusion of innovations overview, it was noted that innovation within the organizational setting occurs in two phases: the initiation phase and the implementation phase. The agenda-setting process is the first stage in the initiation phase of an innovation. In this stage, one or more individuals within an organization perceive an important problem and then set out to identify an innovation as a potential means for addressing the problem (Rogers, 2003). This stage may involve an extended period of time, including several years. A perceived gap in performance, the difference between an organization's expectations and actual performance, can activate the innovation process; although awareness of an innovation rather than a perceived need may also initiate the process. Rogers concludes the discussion of this stage stating, "Setting the agenda for innovation in an organizations is tremendously powerful" (p. 423).

In linking Rogers's discussion of agenda-setting within the context of the diffusion process to the agenda-setting process as typically defined by communication scholars examining media, public, and policy agendas, it is important to note that agenda-setting as applied in this study is subsumed within the diffusion process rather than standing apart from it. Agenda-setting in the innovation process and in its traditional application both state that problems within a social system are identified and prioritized. Some problems receive attention, while others do not based, in part, on the competing powers of issue proponents seeking to set the agenda, whether it be that of the media, the general public, or administrators and coworkers in the organizational setting.

In this study, Licklider, a member of the research community, identified a performance gap between current computing productivity and its potential productivity. His rationale for promoting a symbiotic relationship was based on a personal experiment in which he determined that 85% of his time was spent getting into a position to research rather than actually engaging in the research. He felt certain that computing technology could be advanced to a point where computers and humans worked together interactively and more efficiently than in the current model, and he set out to convince others of his vision via interpersonal connections, conference presentations, and journal publications. While agenda-setting in the communication discipline traditionally focuses on the mass media, more specifically the news media, this study expands the application of the agenda-setting process to the diffusion of a set of ideas among members of a research community. If we take the 1922 observation of Robert E. Park about the roles of news reporters and newspaper editors, which Dearing and Rogers (1996) describe as the pre-definition of agenda-setting, and substitute the actors for this study, it reads:

> Out of all the events that happened and are recorded every day by [professional and academic researchers], the [journal editor] chooses certain items for publication which he [or she] regards as more important or more interesting than others. The remainder he [or she] condemns to oblivion and the waste basket. There is an enormous amount of [research] "killed" every day (cf. Dearing & Rogers, 1996, p. 10).

More specifically, in comparison to mainstream agenda-setting research this study applies the process to a smaller social system, the research community, rather than to the general public. With respect to the mass media, this study applies agenda-setting to a specific channel of mass communication, the research journal, and it acknowledges how publication practices help to determine which studies are published by whom and why. In terms of the media, public, and policy agendas traditionally examined by agenda-setting, this study examines the media agenda, as represented by the role of research journals in communicating ideas, and the public agenda, as represented by members of the research community. The methods used in this study differ somewhat from the usual methods employed in mainstream agenda-setting research. For the media agenda, qualitative content analysis is used to identify the research agenda set forth by Licklider in "Man-Computer Symbiosis." For the public agenda, citation analysis identifies those members of the research community who cite "Man-Computer Symbiosis" in their own publications, referred to as the influence network. Using citation analysis in this study serves a function similar to the filter question used by McCombs and Shaw (1972) to select the 100 undecided voters that were interviewed; it taps into the subjects of interest. Quantitative content analysis examines the content of the citations to determine which of the ideas in "Man-Computer Symbiosis" were referenced in subsequent publications in order to determine if some ideas were more salient among citing authors than others. Agenda-setting also explains how the various positions held by Licklider (e.g., opinion leader, scholar, director of IPTO) effectively positioned him to set an agenda and to have it adopted by members of the research community.

When the larger historical context is taken into consideration, an agenda-setting framework is relevant to this study given its ability to provide insight into Licklider's success at communicating his ideas for human-computer symbiosis. The historical overview presented in Chapter One indicates that in keeping with the agenda-setting function, Licklider held positions within the academy, the private sector, and high level governmental departments—the IPTO—that provided him with the financial power (i.e., funding), the credibility via the prestigious positions he held, and the access to communication channels to share his vision. An emphasis of this study is to further explore the influence network created by the publication of "Man-Computer Symbiosis" for evidence of the agenda-setting process at work within a subset of researchers, as indicated by idea salience in citations over time.

Rationale

Although other analytical frameworks, such as network analysis or systems theory, could be applied in this study, a diffusion of innovations perspective coupled with agenda-setting is particularly well suited to the task of examining Licklider's influence in the realm of human-computer interaction. Diffusion contains an element of time that is necessary to consider when examining the spread of an innovation through a social system. Diffusion also examines the communication channel through which information about the innovation is shared among networks of people. Agenda-setting explains how certain issues and topics are made more or less salient to others over time. Agenda-setting also examines how media, public, and policy agendas are set and by whom.

As a member of a larger research community or network, Licklider had at least three channels by which to communicate his ideas for human-computer symbiosis: informal conversations, conference presentations, and journal publications. In this study, we are interested in the initial publication, “Man-Computer Symbiosis,” that presented Licklider’s ideas for interactive computing. Within the research community, journal publications are a highly regarded form of communication given their general reputation of representing solid work judged to be of importance via the process of peer review and other editorial gate keeping functions. Additionally, compared to informal conversations and conference presentations, journal publications are the most accessible because they are often indexed for future reference. Journal articles are also listed in citation indexes that provide cited reference information for the purpose of tracking subsequent references made to these articles. Citations contain information about the ideas referenced from “Man-Computer Symbiosis.” In turn, identifying the presence of Licklider’s ideas in these citations offers a more detailed view about what citing authors selected to incorporate in their own research, a measure of influence.

Research Questions

Based on the preceding discussion, the two guiding research questions for this study ask:

RQ1 In Licklider’s article, “Man-Computer Symbiosis,” what ideas for improving the human-computer relationship were communicated to promote a research agenda for others to consider?

RQ2 Among the authors citing “Man-Computer Symbiosis,” what do the frequencies and patterns in citation to Licklider’s ideas reveal about the article’s spread and influence among these individuals?

The two research questions prompt an analysis of the specific ideas set forth by Licklider in “Man-Computer Symbiosis,” the diffusion of these ideas via subsequent references made to the article, and the patterns in the diffusion of these ideas across authors, institutions, disciplines, subject areas, and time. The research agenda set forth in “Man-Computer Symbiosis,” as represented by the six ideas includes: *symbiosis*, and improvements to *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. Analyzing the content of citations to "Man-Computer Symbiosis" identifies the distribution and salience of these ideas in others' research.

Study Variables

To assess the spread of the main ideas contained in "Man-Computer Symbiosis," a number of variables are examined to improve understanding about the article's influence on the research community, specifically within the realm of scholarly publications citing Licklider. The study variables can be divided into two groups: article information and citation information. The article information variables include: *author name*, *author position*, *institutional affiliation*, *journal title* and *year of publication*. The citation variables measure the presence or absence of the six ideas: *symbiosis*, *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. Three additional variables not included in the citation and content analyses are: *journal subject area*, *article subject area*, and *position of citations*.

For articles citing "Man-Computer Symbiosis," identification of the authors supplies information about the article's spread among individuals. Analyzing author name also reveals if citations to Licklider cluster within in a small group of authors who cite him multiple times or if citations to Licklider are diffused among a wider variety of authors. Knowledge about authors' affiliations provides information about the article's reach among the academic, government, and private sectors. Recording the year of publication and journal title for each citing article provides information related to changes over time in the frequency of citations and the types of journals in which the subsequent articles appear. Likewise, knowledge about the journals' general subject areas serves to illustrate the article's influence within and across disciplines, illustrating the heterophilous and/or homophilous nature of these groups. The article subject areas, based on the article titles, provide the context in which Licklider's work is cited in terms of subject matter, which assists in tracing the spread of his research agenda among these works. Lastly, identifying the presence of the six ideas in "Man-Computer Symbiosis" within the citing articles indicates which ideas were more or less salient to other researchers along with changes, if any, that have taken place over time. Lastly, the position of a citation within an article reveals if it is used to introduce other research topics, support theory or historical information, support procedures and results, or support overall conclusions.

Chapter Summary

A combination of diffusion of innovations, the primary perspective, and the agenda-setting function, a supplemental perspective, guides this investigation into the spread and influence of ideas contained in “Man-Computer Symbiosis” within the research community over a 40-year period. In this study, the network of articles citing Licklider between 1960-2001 represents a segment of the research community. The network is predominantly composed of career and academic researchers who publish in scholarly outlets including conference proceedings, texts, and research articles. This study focuses on citing articles published in research journals listed in the ISI citation indexes.

Diffusion of innovations explains the process by which an innovation is communicated via certain channels to members of a social system over time. This study applies specific elements of diffusion of innovations in its goal to analyze the spread of Licklider’s ideas among the research community. The specific elements applied include the characteristics of diffusion networks (homophilous and heterophilous), the role of opinion leaders and change agents, agenda-setting in the initiation phase of an innovation, and diffusion over time. Agenda-setting explains how certain individuals or groups who are in the position to promote certain issues and topics make these issues and topics salient in the minds of others. In this study, agenda-setting explains the how the various positions held by Licklider positioned him to set a research agenda in computing. Agenda-setting also guides the analysis of Licklider’s influence among citing authors by identifying which ideas are more or less salient across the citations. The specific variables examined include: *author name*, *author position*, *institutional affiliation*, *journal title*, *journal subject area*, *article subject area*, *year of publication*, *position of citation*, *symbiosis*, *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*.

The next chapter outlines the methods of data collection for the abovementioned variables. Citation analysis identifies the influence network as represented by articles containing citations to “Man-Computer Symbiosis” between the years 1960-2001. Additionally, citation analysis identifies the variables *author name*, *journal title* and *year of publication* for each citing article. Quantitative content analysis then examines each citing article produced by the citation search and verifies the variables identified by the citation search. The content analysis also covers the variables *author position*, *institutional affiliation*, *symbiosis*, *speed mismatch*, *memory* *hardware*, *memory organization*, *the language problem*, and *input/output equipment*. Independent analyses provide information about *journal subject areas*, *article subject areas*, and *position of citation*.

CHAPTER FOUR

METHODS

To assess the spread and influence of the ideas in "Man-Computer Symbiosis" among citing articles, fourteen variables were previously identified and justified: *author name*, *author position*, *institutional affiliation*, *journal title*, *journal subject area*, *article subject area*, *year of publication*, *position of citation*, *symbiosis*, *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. This chapter presents the two data collection techniques used by the study to collect information for eleven of these variables: citation analysis and quantitative content analysis (alternative methods are used to assess journal and article subject areas). The chapter is divided into two main sections. The first section presents each method separately and outlines the history, use, strengths, and limitations. The section concludes by examining the benefits of combining the two approaches, first generally and then within the context of this study.

The second section presents the details for how each method was applied to study the influence network generated by citations to "Man-Computer Symbiosis," along with the appropriate data analyses. For the citation analysis, the following information is provided: 1) details about the cited reference search strategy used to identify citing articles, 2) a recheck of the resulting article set to reveal its stability, and 3) the procedures by which copies of the citing articles were obtained. For the content analysis, the following information is presented: 1) the units of analysis, 2) characteristics of the data set, 3) operational definitions, 4) coders, coding procedures, and sampling for pilot testing, and 5) intercoder reliability checks. The data analyses section overviews three factors considered when determining the appropriate analyses: 1) sample vs. population data, 2) level of measurement of the data, and 3) research questions asked/hypotheses proposed.

Before proceeding, it is useful to briefly restate the research questions and the theoretical framework. The first research question asks: In Licklider's article, "Man-Computer Symbiosis," what ideas for improving the human-computer relationship were communicated to promote a research agenda for others to consider? A qualitative reading of the article identified six ideas related to fostering a symbiotic relationship between humans and computers. Subsequent readings of the article by thirteen undergraduate students who participated in the study confirmed the six ideas. The second research question asks: Among the authors citing "Man-Computer Symbiosis," what do the frequencies and patterns in citation to Licklider's ideas reveal about the article's spread and influence among these individuals? The theoretical framework that guides the examination of these questions combines the diffusion of innovations and agenda-setting function perspectives. The links between the research questions and the theoretical framework were discussed in the previous chapter. This chapter focuses on linking the data collection techniques with the research questions and the theoretical framework

Citation Analysis

Citation analysis is part of a broader methodology known as bibliometrics. In general, bibiliometric analysis is a broad research technique that uses quantitative analysis and statistics to examine patterns of publication within a given field or body of literature (Palmquist, 1999). Bibliometric analysis focuses primarily on five aspects of documentation: 1) the contribution of a particular author (Ruff, 1979), 2) the identification of a watershed work's influence network (Institute for Scientific Information, 2002a), 3) the identification of core journals in a field (Black, 2001), 4) to measure the productivity of an individual, a journal, or a field (Spiegel-Rosing, 1977), and 5) to assess the impact of a particular author or work (Black, 2001). Bibliometrics and its special applications are limited to examining formal channels of scholarly communication (Borgman, 1989).

Within bibliometrics research, there are at least three special applications: citation analysis, co-citation coupling, and bibliographic coupling. Citation analysis is used to identify formal patterns of communication (Harter, 1996) by examining the relationship (e.g., frequencies, percentages, correlations) between authors, works, journals, fields, and/or countries (Beniger, 1988; Palmquist, 1999). Co-citation coupling examines the relationship between two works cited in another work. To illustrate, if A and B are cited by C, then A and B are said to be related, even if they do not cite each other. The more often A and B are cited together, the stronger the relationship between the articles. In bibliographic coupling, the relationship between two works citing the same source(s) is examined. That is, if A and B cite C, they are said to be related, even if they do not cite each other. The more works A and B cite in common, the stronger the relationship between the two.

Citation analysis is of particular interest to this study because it identifies the set of articles and individuals (referred to as the citation or influence network) incorporating into their own research the ideas presented in "Man-Computer Symbiosis." Additionally, as Rogers and Dearing (1993) observe, "Citation analysis can help illuminate the intellectual history of a research tradition, providing a quantitative balance to more interpretive measures" (p. 74). The method gained recognition in the late 1960s with the creation of the *Science Citation Index* by Eugene Garfield, who also founded the Institute for Scientific Information (ISI) in 1958 (Garfield, 1979; Institute for Scientific Information, 2001c). Garfield, outlining the use of citation analysis in historical research, describes it as a method that "…provides a way of identifying key events, their chronology, relationships, and relative importance, and that it is a very useful tool in working out the history of a given scientific effort" (p. 93). It is also a method that "…greatly simplifies the effort involved in constructing the sequence of events and web of relationships that serve as the starting point for the evaluations, interpretations, and explanations that are the essence of historical research" (p.96). Both of these definitions are relevant to the substantive goals of this study, which are to trace the spread and influence of a set of ideas over time.

In its basic form, a citation is a footnote, parenthetical notation or other formal reference included within the text of a publication that represents an author's acknowledgement of others' works (source articles) and their influence (Institute for Scientific Information, 2002a). Examining citation patterns can reveal (underlying) relationships that function among published works. More specifically, and of particular interest to this study, "Often times, a single article can be the foundation for the architecture of an idea. Therefore, by tracing the path of an article through its citations, researchers can navigate through time to discover how an idea may have evolved into a respected scientific concept, theory or practice" (Institute for Scientific Information, 2002a)—a goal, subsequently, that ties in well with the objective of a diffusion perspective: to examine the spread of an innovation over time.

Science Citation Index, first published in 1961(currently searchable from 1955 to the present), allowed researchers to examine citation patterns more easily than previously possible due to its organizational structure. The basic structure of the citation index was founded on the footnote/reference lists of publications. These lists were compiled into a searchable index, originally print-based and now also available in electronic format. The citation index differed from the traditional publication indexes that limited searching primarily to the source article's author, subject, and title—much like a library card catalog—in that it provided searchable access to information on citations to a source article. Enabling individuals to examine the citation patterns of researchers was based on a larger goal within the scientific community specifically and the research community generally: to assess the worth of authors' contributions based partly on the extent to which their works are incorporated into the public domain of knowledge (Merton, 1979). As Robert Merton elaborates, "The greatest ambition of a productive scientist is to do the kind of work that will be much used and much esteemed by fellow scientists best qualified to assess its worth. And, in general, scientific work is esteemed in the measure that others can draw upon it to advance their own future inquiry" (p. viii). The underlying assumption is that citing others' research acknowledges the influence of those individuals on those who are citing them; hence, citation functions as a measure of influence (McVeigh, 2001).

Following the creation of *Science Citation Index*, two additional citation indexes have been developed: *Social Sciences Citation Index*, first published in 1972 (currently searchable from 1956 to the present) and *Arts & Humanities Citation Index*, first published in 1978 (currently searchable from 1975 to the present)(Institute for Scientific Information, 2001c). The advent of networked electronic versions of these indexes and the recent *Web of Science*, which allows seamless simultaneous searching of all three indexes, enables researchers to more easily conduct citation searches across geographical and disciplinary boundaries to assess better the reach of a cited work. This said, the ISI citation indexes are not necessarily the only indexes available to researchers, but, at this time, they appear to offer the broadest and most sophisticated coverage enabling "users to search current and retrospective multidisciplinary information from approximately 8,500 of the most prestigious, high impact research journals in the world. *ISI Web of Science* also provides a unique search method, cited reference searching" (ISI, 2002b). Also, as is apparent from the discussion on the co-development of citation analysis and citation indexes, the method and the ISI indexes are inextricably linked.

Generally speaking, citation analysis involves conducting a cited reference search—by author, journal title, and/or year of publication—using print and/or electronic citation indexes, such as the aforementioned ISI citation indexes. More sophisticated database searches may also be used for trend analysis, and for the co-citation and bibliographic coupling techniques mentioned previously (Tenopir, 2001; Wormell, 1998). Results of these searches are reported using frequencies, percentages, and more advanced inferential statistics, where appropriate, and can be used to identify rates of decay (i.e., the decline in citations to a source over time) as well as to track the spread of ideas over time (Dieks & Chang, 1976).

Strengths

Citation analysis, and bibliometrics generally, is a powerful tool for examining a wide range of relationships in the realm of published works. There are at least three primary strengths with this research approach. First, citation analysis is unobtrusive in that it examines the artifacts of communication (e.g., journal articles, citation index listings). The method does not require direct contact with an individual who may be unavailable or unwilling to be studied directly. The method's unobtrusive nature makes it highly reliable in that the data examined are readily available and the results can be reproduced easily (Borgman, 1989). Second, citation analysis excels at empirically identifying and verifying relationships between authors, works, journals, fields, and/or countries via a systematic approach to data collection followed by statistical analyses that help to reveal citation patterns (Garfield, 1979). Third, citation analysis provides a macro-level picture of an author's work or collection of works over time that cannot be achieved by surveys, case studies, or interviews (Borgman, 1989).

Limitations

Citation analysis has a number of limitations that can be divided into three main areas: reliance on citation indexes/misuse of citation, limited coverage by citation indexes, and lack of contextual information. First, citation analysis relies heavily on the use of citation indexes—such as the ISI Arts & Humanities, Social Sciences, and Science Citation indexes—for data collection. While citation indexes are generally accurate, errors and misuse do occur. For example, data may be entered incorrectly (e.g., misspellings) into the citation index or an author may incorrectly cite another author, a title, and/or a year of publication. If these errors are recorded and spread throughout the citation indexes they produce an inaccurate (i.e., under-represented) picture of an author's contribution. Less experienced users of citation indexes who are not aware of these limitations may unknowingly draw research conclusions based on an incomplete data set. At the other extreme, authors wishing to elevate their citation counts for the purpose of gaining recognition (e.g., for tenure and promotion) may gratuitously cite themselves or others in their close circles thus assigning an artificial importance to the cited authors or cited works (MacRoberts & MacRoberts, 1986). Under or over-representation calls into question the validity of cited reference search results (Borgman, 1989). These errors and misuses lead some researchers to question the usefulness of citation analysis, particularly when it is used as the primary tool to assess the contributions of an individual with respect to awarding tenure and promotion within the academy. Early on, Garfield (1979) himself cautioned against relying solely on citation analysis in this specific context, as quantity does not necessarily equate with quality, but these warnings have not entirely dissuaded individuals from misappropriating the method.

Second, due partly to economic and feasibility factors, citation indexes do not index all scholarly and professional journals, therefore it is not possible to identify completely all references made to a source article or author; thus, the influence network identified by a cited reference search is at best a conservative estimate of the source article's overall spread and influence. Currently, the ISI indexes cover approximately 8,500 journals that research indicates are mainstream, highly valued, and influential publications. Justification for not covering all journal titles is based on a bibliometric principle known as Bradford's Law (Institute for Scientific Information, 2001b). In general, Braford's Law states that a core set of journals produces one-third of the total published articles in a field, a second larger set of journals produces another one-third of the articles, and a third even larger set of journals produces the other one-third of the articles. While statistically inexact, this law is used as a guide, for example, in collection development within libraries and in selecting journals for coverage in citation indexes (Palmquist, 1999). The ISI indexes have also been criticized for primarily indexing mainstream research in industrialized nations, thus omitting the research contributions of developing countries (Velho & Krige, 1984). Lastly, not all disciplinary publications are represented equally in the ISI indexes. For example, the research journals in the Communication discipline tend to be under-represented (i.e., not contained in the citation indexes) by ISI in comparison to other fields (Funkhouser, 1996). Clearly, not all journals are included in the ISI indexes, and this limitation should be kept in mind when reading the results and discussion of this study.

Third, citation analysis frequently does not account for the context in which the author, work, or journal is cited (Small, 1978). That is, without a close inspection of the work itself, it is difficult to tell if the author or work being cited is done so with praise or criticism, to build or challenge theory, and so on. This particular limitation lies at the heart of a basic assumption of bibliometric analysis, generally, and citation analysis, specifically, that the impact of authors' and their works is generally a positive one—an assumption that can be false. Additionally, citation analysis, and bibliometrics generally, focus on formal channels of communication, thus missing important informal influences on the scholarly publication process. However, this limitation is offset when other methods, such as historical analyses and interviews, are used to supplement the information produced by citation analysis (Borgman, 1989). Such is the case with this study, which supplements the quantitative methods with information provided by Internet and oral histories.

Quantitative Content Analysis

Before defining content analysis, it is important to note that there are two approaches to this methodology: qualitative content analysis and quantitative content analysis. Qualitative content analysis may be likened to textual analysis in that it is primarily interpretive in nature, is typically based on an individual's perspective, and frequently does not employ statistics for data analysis. Quantitative content analysis is a research method used to make valid and reliable inferences from the data to their context (Krippendorff, 1980). It is the systematic assignment of communication content to categories according to specified rules, and the statistical analysis of the relationships between those categories (Riffe et al., 1998). Lastly, it is a social scientific methodology that requires researchers to make strong arguments for the validity and reliability of their data (Potter & Levine-Donnerstein, 1999).

Holsti (1969) defines content analysis as the application of scientific methods—characterized by the terms objectivity, systematic, and generality—to documentary evidence. By objectivity, Holsti refers to the application of specific rules and procedures during data collection that minimize researcher bias. By systematic, Holsti refers to the development of categories to identify the inclusion/exclusion of content and the consistent application of those categories to communication content that offset the potential for data to be collected that *only* support the researcher's questions and/or hypotheses. Generality refers to the identified relationship, guided by theory, between the data and the producers and/or recipients of the data—a guiding premise in the scientific method.

The basic steps to conduct a quantitative content analysis are: 1) a set of research questions and/or hypotheses is formulated, 2) appropriate theory or theories are identified to guide the analysis, although exploratory research may occur without theory, 3) the relationship between the questions/hypotheses and the theories are operationalized into measures (e.g., author names, article titles, year of publication, keywords), which are coded into categories that, ideally, are exhaustive, mutually exclusive, valid, and reliable, 4) a code book, also known as a coding protocol, is created that contains the content categories and the rules for evaluating content for inclusion/exclusion, 5) a data set is selected and justified, 6) coders are trained to use the code book, 7) a pilot test is conducted on a random sample of units to assess intercoder reliability (the degree to which the coders agree on what they've seen, correcting for chance agreement where possible) and, if necessary, adjustments are made to the code book to improve this reliability, 8) the main study is conducted and intercoder reliability is assessed again. Within this general approach, additional factors must be considered such as sampling decisions and coder selection and training, but these general guidelines illustrate Holsti's (1969) reference to the objective, systematic, and generality characteristics discussed previously.

Although most frequently applied to the mass media within the communication discipline, content analysis is a cross-disciplinary research technique that has been used to examine a range of topics (Holsti, 1969). For example, researchers in psychology have applied content analysis to examine interview transcripts of therapy patients, and historians have used the method to identify themes and patterns in political documents. In general, it is a useful tool for examining messages in text, audio, and visual formats.

Strengths

In general, content analysis has two primary strengths. First, like citation analysis, content analysis is unobtrusive because it examines the artifacts (e.g., texts, images) of communication and not the individual directly. This study benefits from this strength because it examines a range of authors over a 40-year time span. Tracking down each author to inquire into his or her citations to "Man-Computer Symbiosis" would be difficult, if not impossible given that some authors may no longer be alive. Their works, however, are part of the published archive and are more readily accessible. Second, content analysis, unlike citation analysis, is context sensitive (Krippendorff, 1980). It can examine a particular factor in light of its environment (e.g., clothing styles in a music video, the presence of an idea within a citation). This strength is important to this study because in addition to identifying the network of articles citing "Man-Computer Symbiosis," the study also examines what is cited, in the form of ideas.

Limitations

Two primary limitations to content analysis also exist. First, quantitative content analysis by design is primarily limited to examining manifest content—the "what you see is what you get," superficial face value of the content (e.g., the number of times the term "symbiosis" appears in an article, the number of violent acts in a portrayal)—as opposed to latent content—the "reading between the lines" value of the content (e.g., the degree to which an author's ideas are favorably or unfavorably referenced, the degree of violence in a portrayal), which Potter & Levine-Donnerstein (1999) argue is more interesting and potentially more useful to understand than manifest content alone. Both Holsti (1969) and Riffe et al. (1998) subscribe to the perspective that manifest content is all that content analysis can examine and that interpretation of meaning should occur after data collection in the discussion section. Potter and Levine-Donnerstein argue for the examination of latent content *during the coding process*, for example, via the gradual surfacing of group norms in the process of coder training. They further divide latent content into *latent pattern* and *projective* content and make the following distinctions:

- *Manifest content* is that which is on the surface and easily observable, such as the appearance of a particular word in a written text, the gender of a character in a film, or certain behaviors (blinking eyes, scratching head) in interpersonal conversations [emphasis added].
- With *pattern content*, the designer of the content analysis puts precedence with the content and believes that there is an objective pattern there that all coders should uncover by sorting through symbols and recognizing the connections among them [emphasis in original].
- In contrast with *projective content*, the researcher puts precedence with the coders' judgments and believes that the elements in the content are symbols that require

viewers to access their pre-existing mental schema in order to judge the meaning in the content [emphasis in original] (p. 259).

Although an interesting argument, the dominant perspective on content analysis appears to be that it is limited to manifest content. This study expands on the argument to demonstrate that quantitative content analysis can successfully identify content possessing latent characteristics.

A second limitation of content analysis is that it is almost a purely descriptive research technique. This limits the ability of researchers who rely solely on this method to measure effects. That is, the method focuses primarily on message content, but it does not necessarily address how the audience perceives and processes the message content. However, when content analysis is combined with another method that is better suited to measuring effects (e.g., experiments, surveys, citation analysis) and that can evaluate the producer and/or receiver of the content, statements about effects are better supported and defended (Holsti, 1969; Gunter, 2000).

Combining Data Collection Techniques

Generally speaking, combining methods—whether they are quantitative, qualitative, or a mixture—often produces a stronger study than does relying on a single method. Citation analysis coupled with content analysis produces a combination of data collection techniques that maximizes their strengths while minimizing their limitations (Chubin & Moitra, 1975). Citation analysis excels at identifying influence networks as represented by citing works and their authors, but it is weak in analyzing the context or content of those citations because it only identifies authors, journal titles, article titles, and publication years for the citing works. Citation analysis tells us nothing about the citations in the citing works; it only indicates that the source article is referenced in a citing work. In this study, citation analysis identifies the set of individuals who referenced "Man-Computer Symbiosis" in their own works and allows us to examine the spread and influence of Licklider's article within the research community on a very general level that is limited to the characteristics of the articles (e.g., author name, year of publication). Citation analysis does not identify the specific citations to Licklider, their number within an article, or which ideas from "Man-Computer Symbiosis" appear in the citations.

In contrast, content analysis is strong at examining communication in its context but weak in linking to effects directly. That is, in the general Source—Message—Channel—Receiver (SMCR) communication model, content analysis focuses on the meaning of the message that is being communicated, whereas citation analysis identifies the source (e.g., Licklider's article), the channel (e.g., scholarly publication), and the receiver (e.g., citing works and their authors) components of the model. Combined, the two approaches can effectively 1) identify the influence network of "Man-Computer Symbiosis," 2) identify the ideas in Licklider's article that were cited by subsequent authors, and 3) produce a set of findings that rest on a strongly defensible foundation based on systematic and reliable data collection.

Another benefit derived from combining these methods is the ability to demonstrate the effectiveness of this combination to the other researchers. Within the communication discipline, it has been recognized that bibliometrics combined with content analysis produces more robust findings about communication producers, artifacts, and concepts than either method alone (Borgman, 1989; Borgman & Paisely, 1989; Paisley, 1989). Although studies of scholarly communication couple citation analysis and content analysis (for examples, see, Velho & Krige, 1984; Cronin, Davenport, & Martinson, 1997), closer examination reveals that many of these studies have not clearly established that quantitative content analysis was used, which weakens their inferences.

For example, a study by Velho & Krige (1984) identified the citation network of Brazilian agricultural scientists and then used content analysis to examine the articles; however, the reporting of the method in their article was insufficient to be of much value from the perspective of a quantitative content analyst. It appears that some form of coding took place judging by the categories into which the citing articles were grouped (e.g., self-citation = S, in-house citation = H; for details, see full paragraph #2, p. 48). The authors reported that, "All of these papers were carefully read and their contents and reference lists were closely analyzed" (p. 48). However, no operational definitions were provided to match the concepts in the study with the actual measures coded. Mention of a coding scheme, the coders, a code book, coder overlap, pilot testing, and coder agreement were also missing from the article. The authors did, however, provide a rationale and a detailed overview regarding the (non-random) sampling of the articles, but this greatly limited their ability to make general claims about the Brazilian agricultural science community, which was a goal of the study.

The most one can conclude from the study's reporting is that a rough cross between a qualitative and quantitative approach was used to collect data from the articles. In terms of the reliability and validity of the findings, little can be inferred given the lack of reporting;

methodologically, the study is the weaker for this. It seems that, given the objective of the authors to speak about the state of research in the Brazilian agricultural research community (compared to industrialized nations) and the desire to suggest policy changes, the study's findings would have been better supported if a more rigorous empirical investigation designed to permit generalizations had been used. As it stands, this study falls short of its overall purpose to speak about the productivity of Brazilian researchers because it can only speak to the 41 papers it examined.

Additionally, researchers who report using content analysis frequently fail to elaborate on their application of the method making it difficult for others to understand their procedures and to replicate their findings; if, in fact, these are goals of the studies, which remains unclear given the methodological vagueness. Despite articles and books addressing these issues, problems related to vague application and reporting persist with quantitative content analysis (Lombard, Snyder-Buch, & Bracken, 2002).

In contrast, this study utilizes the strength gained by combining citation analysis with quantitative content analysis to examine the spread and influence of "Man-Computer Symbiosis" among citing articles. The characteristics of objectivity, systematic, and generality inherent in quantitative content analysis, if conducted effectively, provide a strong foundation from which to examine the spread and influence of Licklider's ideas. Of course, as with all research designs, there are limitations to this approach, two of which are important to note. First, as Velho and Kirge (1984) point out, reliance on the ISI citation indexes limits one's analysis to mainstream publications in industrialized nations, and thus does not account for all possible publications in which Licklider may be cited. However, given the topic of study, this limitation is acceptable in that much of the Internet's research and development has been a U.S.-based phenomenon (Pavlik, 1998; Waldrop, 2001). Additionally, the ISI Citation Indexes are currently one of the few, if not the only, indexes readily available that provide easily searchable citation information. Second, examining articles that cite "Man-Computer Symbiosis" does not account for those individuals who read the article and were influenced by its content but who did not 1) formally cite him, 2) publish in an outlet indexed by ISI or 3) write about him at all. As such, this study provides a conservative estimate of Licklider's influence because it is limited to analyzing only the published works of citing authors who are included in the ISI indexes.

Research Plan

Citation analysis and quantitative content analysis are the selected methods of data collection for this study. The methods are presented in the order that they are applied: citation analysis and quantitative content analysis. Details for the application of each method are presented along with a corresponding rationale. The research plan concludes with an overview of the analyses appropriate for the data collected in this study.

Citation Analysis

Citation analysis functions in two primary capacities. First, because this study is interested in examining articles citing “Man-Computer Symbiosis,” the method efficiently identifies the data set of articles to be analyzed. A cited reference search in the citation indexes circumvents the need to content analyze all 8500 plus journals indexed by ISI, a daunting task, for the presence or absence of articles citing “Man-Computer Symbiosis” by functioning as a data mining tool. Second, the method identifies the influence network generated by articles containing citations to “Man-Computer Symbiosis.” Identification of this network (i.e., the recipients of the message) fosters inquiry into the article’s influence.

Cited Reference Search Strategy

The ISI Web of Science, available from the Florida State University Libraries’ electronic databases web page (currently available via subscription at, http://www.fsu.edu/library/search/databases/index.shtml), provided access to and simultaneous searching of the three ISI citation indexes: Science Citation Index (1955-present), Social Sciences Citation Index (1956-present), and Arts & Humanities Citation Index (1975-present). A cited reference search was conducted using only the cited author name “Licklider” for all available years (1955-2002). This strategy produced the broadest search possible to identify articles citing “Man-Computer Symbiosis.” The rationale for conducting such a broad search, when it was possible to also supply information about full author name, the publication year, and the journal title, was based on the preceding discussion of the method’s limitations. Namely, errors and variations in works citing Licklider’s name, the journal title, the volume, and/or the year of the publication would be excluded from the results list if a search more specific than “Licklider” were conducted.

The broad cited reference search conducted on the term “Licklider” produced 545 matches to the query. Each result was then examined to see if it matched the “Man-Computer Symbiosis” citation. Not surprisingly, given the idiosyncrasies of citation practices (e.g., APA style versus MLA style) and indexing, articles citing “Man-Computer Symbiosis” were scattered among the 545 matches. For example, one article was listed under the author “LICKLIDER” and the cited work “IRE T HUMAN FACT MAR,” while 59 articles appeared under the author “LICKLIDER JCR” and the cited work “IRE T HUM FACTORS EL.” Another three articles appear under the author “LICKLIDER JCR” and the cited work “MAN COMPUTER SYMIOS”; two more appear under the author “LICKLIDER JCR” and the cited work “MAR IRE T HUM FACT E” (see Appendix A1 for a complete listing of the cited reference search matches for “Man-Computer Symbiosis”). Clearly, a more specific cited reference search conducted on, for example, “Licklider JCR” would have omitted those articles in which “JCR” was not part of the citation information. Why do these variations occur?

As mentioned earlier, citation practices vary over time and citing authors make errors, so variations in cited reference search results are due to a combination of factors. Indexers of citing articles record the information contained in these articles exactly as it is written. Data entry errors can also occur to further complicate matters. Additionally, authors are not always consistent in the use of their names. For example, Licklider may have originally started publishing under “J. Licklider” and then later switched to “J. C. Licklider” and then again to “J. C. R. Licklider,” leading to inconsistent listings for the author’s works. These variations in the citations are recorded in the indexes, so the best approach is to conduct the broadest search possible and then to examine each entry for a match. Out of the 545 matches for the “Licklider” cited reference search, a set of 129 articles matched the citation information for “Man-Computer Symbiosis” (see Appendix A2).

Stability of the Data Set

Citation indexes are not static entities given their goal to keep pace with serial publications. Not only are new records constantly added to keep the databases current with newly published articles, but indexers also add records as they work backward in time to expand the scope of the citation indexes. This raises a question about the stability of the data set produced by the December 2002 search. To check the stability of the number of articles examined in this study, a second cited reference search on “Licklider” was conducted in April 2003. This search produced 132 articles for a difference of +3 articles in a four month time period. The small increase in articles suggests a relatively stable data set for this study.

Obtaining the Articles for Study

The 129 articles citing "Man-Computer Symbiosis" (listed in Appendix A2) were obtained by students enrolled in an undergraduate honors seminar as part of an assignment for course credit that introduced them to the basics of navigating an academic research library. Articles not available from the Florida State University Libraries were obtained via interlibrary loan requests. The students were reimbursed for all related photocopying expenses. Upon receipt of the articles, the footnotes, endnotes or reference lists were checked to verify that each source did in fact contain an entry for "Man-Computer Symbiosis." Three complete sets of articles were reproduced from the original set.

Quantitative Content Analysis

In this study, quantitative content analysis is used to examine the spread and influence of a set of six ideas published in the article, "Man-Computer Symbiosis" among citing articles published between the years 1960 and 2001. The six ideas include: *symbiosis*, *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. Additionally, content analysis verifies the following article variable information provided by the citation analysis: *author name*, *journal title*, and *year of publication*. Lastly, content analysis examines the variables *author position* and *institutional affiliation*, information not provided by the citation analysis. The next section identifies the units of analysis for the content study based on the research questions and the theoretical framework.

Units of Analysis

The context unit of analysis—the smallest meaningful unit given the larger goal for this study, which is to examine the diffusion of Licklider's ideas among those citing him—is the research article citing "Man-Computer Symbiosis." Each citing article represents an individual(s) who was influenced by Licklider's publication. If this study were to, for example, use the individual citations to Licklider contained within the articles as its context unit, then the importance of the individual and his/her institutional and disciplinary affiliations would be lost, thus weakening the analysis of influence. Hence, the individual article and not the individual citation is the context unit for the study.

The recording unit—the smallest unit analyzed—is primarily thematic (e.g., ideas), although general article information (e.g., authors, institutions) and individual words that appear unique to Licklider's piece, such as *symbiosis* and *partnership* are coded. Specifically, coders' attention focuses on the citations made to Licklider with respect to the "Man-Computer Symbiosis" publication, and, if necessary on the text surrounding the citations (i.e., the preceding and/or following sentences or the inclusive paragraph). Coders skimming the reference lists note if additional writings by Licklider are cited in the articles examined, and only those citations referencing "Man-Computer Symbiosis" are coded.

Data Set

The cited reference search conducted in the ISI citation indexes produced a list of 129 articles that comprise the original data set for this study. Upon initial review of the articles, six were automatically omitted because three were written in a language other than English and three were not full articles; this reduced the data set to 123 articles. Given the manageable size of the data set, all articles were content analyzed. One benefit to analyzing all of the articles is that it provides a clearer depiction of changes to and patterns in how researchers incorporate Licklider's ideas into their own works over time.

Operational Definitions

Eleven variables were identified as relevant to the research questions and theoretical framework. These measures are divided into two groups: general article information and ideas set forth by Licklider in "Man-computer Symbiosis." The variables in the general article information grouping include: V1) the full name of each *author*, to identify specific researchers and to check for repeat citers; V2) *author position*, to determine the concepts' spread among types of researchers, V3) authors' *institutional affiliation*, the name of authors' institutions, to examine the spread of ideas across organizations; V4) *publication year*, to identify patterns in citations over time, a key concept in diffusion theory; V5) *journal title*, which functions as another indicator of the reach of Licklider's ideas. In a secondary analysis (not part of the citation or content analyses), the journal titles (V5) are further broken down into *journal subject area* based on the Library of Congress classification system (see Appendix B) to provide information about the spread of Licklider's ideas across disciplines. Secondary analyses also examine *article subject area*, as determined by title keywords and phrases provided by the citation analysis, and *position of each citation* within the citing article to present a clearer picture of how Licklider's ideas were applied (e.g., to introduce a topic, support theory).

The second grouping of variables focus on the six ideas presented in "Man-Computer Symbiosis." Coding for the presence or absence of the ideas identifies which were applied in other researchers' works, with what frequency and pattern. These variables include: V6) *symbiosis*, computers assuming more routine tasks, fostering higher level thinking; and references to specific concepts, V7) *speed mismatch*, V8) *memory hardware*, V9) *memory organization*, V10) *the language problem*, and V11) *input/output equipment* (see Appendix C for code book and coding sheet details). The portion of the code book covering the six ideas is based primarily on the organization and wording used by Licklider in "Man-Computer Symbiosis."

Coders, Coding Procedures, and Sampling

In the spring semester of 2003, seven Florida State University undergraduate students studying communication participated in a semester-long directed individual study (DIS) to gain hands-on research experience in a team setting. The majority of the semester was spent formulating the variables for the quantitative content analysis, creating the code book, and pilot testing the code book to minimize coding inconsistencies. The seven students also conducted independent readings of "Man-Computer Symbiosis" and submitted written summaries containing their interpretations of the main ideas expressed by Licklider. The seven summaries confirmed the presence of the main ideas presented in Chapter Two.

The following fall, six additional Florida State University undergraduate students in communication participated in a semester-long directed independent study (DIS) to gain research experience on this project, primarily as coders. Initial coder training occurred over a three-week period. The first two weeks required the students to read background information on Licklider, the research project, and quantitative content analysis. The first week of readings contained a background chapter on Licklider taken from *Technomanifestos* (Brate, 2002) and the original 1960 publication of "Man-Computer Symbiosis." These students were also asked to summarize the main points of the Licklider article as a way to check earlier readings of the article; all summaries confirmed the six ideas presented in Chapter Two. The second week of readings focused on quantitative content analysis and included three chapters out of Riffe, Lacy, and Fico (1998) and an article by Potter & Levine-Donnerstein (1999) on validity and reliability in content analysis. The order and type of readings gradually stepped the students down from a very broad topic (Licklider) to the specific focus (the spread and influence of ideas in "Man-Computer Symbiosis") in which they played an important role (functioning as coders in the content analysis phase). Once the readings were completed, we met as a group to discuss the links between the readings and the proposed study; to address questions that occurred during the readings, particularly with respect to the role of the coders; and to lay out the next stages of the study: practice coding as a group, pilot testing, and main study coding. In week three, all six students participated in a brief practice coding session to get a sense of what is involved when coding for a quantitative content analysis. The six students were then divided into two coding teams, each comprised of three coders: 1) a citation identification coding team and 2) an article and idea variables coding team.

Phase I: Citation identification coding. The first coding phase involved three coders trained to recognize various citation styles (e.g., APA, MLA, Chicago) and spanned a two-week period. In this first phase of coding, citations to Licklider's 1960 publication were identified in all 123 articles using a set of coding instructions (see Appendix C1). The coders participated in a practice coding session involving a small number of articles (approximately 5) from the data set. Afterward, the students each took a set of articles and coded them independently of one another. Pilot study coding took place during a one-week period, and coder overlap was 100% (i.e., all three coders examined the same set of articles). Simple percentage of agreement, set at a minimum of 80%, was calculated for both the pilot and main studies. Coders met after the reliability checks to discuss coding discrepancies.

Upon successful identification of the citations by the coders, as indicated by the intercoder reliability checks, each citation within each article was assigned an identifier number that linked to the article in which the citation appeared. For example, an article identified as "001" (out of the original 129 articles) containing two citations to Licklider had citations identified as "001A" and "001B." The purpose of this first coding phase was to minimize coder fatigue in the second phase of coding by removing the need for coders to first identify the citations before coding the content of the citations.

Phase II: Article and idea variables coding. The second coding phase occurred during a three-week period. This coding phase focused on 1) the citing article variables and 2) the idea variables contained in the citations identified by the Phase I coding team. As with the first team, the second team reviewed and discussed the code book and coding sheet (see Appendices C2 and C3), participated in a group practice coding exercise, and, in this case, conducted two pilot tests of the code book before moving on to the main study. The practice coding session was conducted on a small selection of the citing articles (approximately 5). The pilot studies were conducted within a two-week period. Coding occurred independently with a 100% coder overlap. Coders met after the reliability checks to discuss coding discrepancies.

Sampling. Pilot studies, which served as a pre-test for the coding procedures and training, were conducted on a sub-set or sample of the total set of articles in this study. A random sample of articles was selected for the Phase I and Phase II pilot studies based on the sample size equation provided in Riffe et al. (1998, p. 125):

$$n = \frac{(N-1)(SE)^2 + PQN}{(N-1)(SE)^2 + PQ}$$

where:

N	=	the population size (number of content units in the study)
SE	=	the standard error of a one-tailed test z-score
P	=	the population level of agreement
Q	=	(1 - P)
n	=	the sample size for the reliability check

To illustrate, the sample size for the Phase I pilot study was calculated as follows: $N = 123$, the total number of articles available for study after removing ineligible articles from the original 129; the population level of agreement is $P = 85\%$ or .85; $Q = (1 - 0.85) = 0.15$; and the SE (standard error) = 0.05/1.64 (where 0.05 reflects a willingness to be incorrect in the assessments +/- 5% of the time and 1.64 = a one-tailed z-score, the number of standard errors needed to include 95% of all possible observations) = 0.03. Given these values, the sample for the pilot study was 67 articles. Based on this equation, the coders trained for an 85% agreement level in order to meet the minimum 80% agreement level, mentioned earlier, because this calculation includes a ± 5% confidence interval; thus if coders agree 85% of the time on a variable and a ± 5% confidence interval is constructed around this calculation, then this means that the agreement between coders could be as low as 80% or as high as 90%. The minimum simple agreement of 80% is a commonly accepted level in communication research (Riffe et al., 1998).

Intercoder Reliability

Given the manageable size of the data set, coder overlap for all phases of the study was 100%. The benefit of having a complete overlap is that it maximizes the number of units in the overlap to give a clearer picture of where code book and coder discrepancies occur. Additionally, the use of three coders rather than two reduces the potential for profiting from chance agreement. Simple percentages of agreement were calculated for all variables coded in the content analysis. In cases where a variable had a finite number of possible coding responses (e.g., coding options for the variable *symbiosis* = 1, for present, or 0, for absent), corrections for chance agreement were calculated to further reduce coder agreement profiting from chance.

Selection of the chance agreement correction test depends on the number of coders and the level of data measured in the study (Lombard et al., 2002). In this study, there were three coders per coding team and the data were primarily nominal level measures. Scott's pi correction for chance agreement is suitable under these conditions (Potter & Levine-Donnerstein, 1999). Within the communication discipline, an intercoder reliability coefficient for chance agreement of 0.8 or higher is the standard acceptable level; however, for studies dealing with less researched topics and/or variables that are more latent in nature, a 0.75 level is acceptable (Riffe et al., 1998). This study applied the 0.8 level to the article information variables (e.g., *author name*, *year of publication*), which were manifest, and the 0.75 level to the idea variables (e.g., *symbiosis*, *speed mismatch*), which possessed latent content characteristics. The intercoder reliability levels—simple percentages of agreement and corrections for chance agreements (where applicable)—are reported for each variable.

Data Analysis

Broadly speaking, the types of statistical analyses applied to a data set are guided by sampling decisions based on population size, the level of the data collected (i.e., nominal, ordinal, interval, or ratio), and the study research questions and/or hypotheses. Inferential statistics are analyses performed on random samples drawn from a population that enable claims resulting from the analyses of the sample to be generalized (i.e., inferred) to the larger population from which the sample was drawn. Descriptive statistics are limited to only describing the data at hand. Most statistically oriented studies draw samples because the populations they wish to examine are quite large (i.e., very difficult to obtain), and sampling is an effective and feasible alternative to analyzing the entire population (Brewer, 1996). Though technically still a sample and not a population, in part because some articles were excluded, this study examines a finite set of publications produced from a cited reference query in the ISI citation indexes. The goal of this study is to make statements about the spread and influence of ideas contained in "Man-Computer Symbiosis" among a specific set of citing articles published between 1960-2001. It is not a goal of the study to infer beyond this set of citing articles. In this case, descriptive statistics are appropriate for analyzing the data produced by the citation and quantitative content analyses, as well as the follow up analyses.

The level of the data—nominal, ordinal, interval, and ratio—also plays a role in determining the types of analyses conducted. Nominal level data is the “lowest” level in that the data are observations that divide into discrete subclass categories but cannot be meaningfully ranked or averaged (Siegel & Castellan, 1988). An example of a nominal level variable is ice cream flavor, which can then be divided into discrete categories such as chocolate, strawberry, and vanilla. Ordinal level data possess the character of nominal level data in that they divide into discrete categories, however, these categories can be ranked meaningfully into a hierarchy. Continuing with the ice cream example, an ordinal level variable is serving size, which can then be divided into small, medium, and large. In this example, the subclass categories can be ranked according to the amount of ice cream contained in a serving.

The interval level of data contains characteristics of nominal and ordinal levels but adds the characteristic of continuousness whereby distances between data points at this level have substantive meaning, although the zero point and unit of measurement are arbitrary (Siegel & Castellan, 1988). An example of the interval level is the Fahrenheit temperature scale used to refrigerate the ice cream. In the Fahrenheit (F) scale, freezing occurs at 32 degrees and boiling at 212 degrees. However, another commonly used scale, Celsius (C), registers freezing at 0 degrees and boiling at 100 degrees. Although both scales measure points of freezing and boiling, they use different numbers to represent these events and the difference between the ratios of these scales is not equivalent (to convert from F to C, the C reading must be multiplied by 9/5 and have 32 added). The ratio scale includes characteristics of the three scales previously discussed but differs in that is has a true zero point and “the ratio of any two scale points is independent of the unit of measurement” (p. 30-31). An example of the ratio level is the measurement of the weight of an ice cream tub. A scale in ounces/pounds and a scale in grams both have true zero points such that the ratio of the ice cream tub’s weight in ounces/pounds is equivalent to its weight in grams. The level of the data determines the types of statistical analyses that can be appropriately applied. In general, nominal level data are the most limited with respect to available analyses, but this does not automatically mean that the results of nominal level analyses are less valuable than the other data levels. Rather, researchers must be sensitive to the level of the data so that appropriate analyses are conducted to produce meaningful results.

Finally, the study research questions and/or hypotheses guide the type of analyses applied to the data. Depending on the study objectives, analyses may be conducted to simply describe the data, to chart patterns in the data over time, to investigate direction and/or magnitude of relationships between variables, to investigate differences between variable groups, to predict outcomes based on the results of current data, or some combination. Clearly, the selection of statistical analyses is a complex process involving a series of decisions tied into the study objectives, sampling, and the levels of the collected data.

This study examines the spread and influence of ideas contained in "Man-Computer Symbiosis" among citing articles published in scholarly journals between the years 1960-2001. The number of articles fulfilling the study requirements is small enough that an analysis of all articles is conducted, and the study only seeks to make statements about this set of articles. The majority of the study variables are at the nominal level (e.g., author name, affiliation, journal title, presence or absence of ideas) of measurement, though some data are at the interval and ratio levels (e.g., year of publication, number of citations per year). Based on this information and the previous discussion, data analyses for this study are primarily descriptive in the form of frequencies and percentages. Additionally, the timeframe covered, 1960 – 2001, lends itself to depicting patterns of citation to "Man-Computer Symbiosis" using graphs and other illustrative tools. In a few instances, tests for independence and co-variance between groups of variables are conducted to determine if differences exist, for example, between the general subject area of a journal in which a citing article is published and citations to the six ideas.

Chapter Summary

This chapter provides an overview of the two methods used to collect data for the study, citation analysis and quantitative content analysis, and links them to the guiding theoretical framework. Diffusion of innovations links with citation analysis to detect the general spread of the article, "Man-Computer Symbiosis," among citing authors, institutional affiliations, journals, and years of publication. Diffusion of innovations also pairs with quantitative content analysis to specifically examine the spread of the six ideas contained in "Man-Computer Symbiosis" among citing authors, institutional affiliations, journals, and years of publication. Agenda-setting combines with citation analysis to identify the authors who noticed and reacted to "Man-Computer Symbiosis" by citing the article. Agenda-setting partners with quantitative content analysis to identify which of the six main ideas communicated by Licklider are more or less salient in citing authors' research over time. The study objectives combined with the characteristics of the data set—a finite set of articles, primarily nominal level measures—guide the statistical analyses that produce the study results. The following chapter presents the results of the intercoder reliability checks conducted during the content analysis and the statistical analyses performed on the resulting data set.

CHAPTER FIVE

RESULTS

To examine the spread and influence of "Man-Computer Symbiosis" among citing articles between 1960-2001, this study combines citation analysis and quantitative content analysis to produce the data set. Citation analysis identifies the influence network for "Man-Computer Symbiosis" as represented by articles citing the work. Quantitative content analysis verifies and adds to the article information provided by the ISI cited reference search and identifies the presence or absence of Licklider's six ideas within the citations of each article. The chapter begins with a summary of the final data set and then presents the results of the intercoder reliability checks conducted for the content analysis phase of the study. The chapter then reports the results of the statistical analyses conducted on the data set generated by the citation, content, and follow-up analyses. Interpretations of these analyses are presented in the Discussion section (Chapter Six) immediately following the results.

Final Data Set

The original results set produced by the ISI cited reference search contained 129 articles citing "Man-Computer Symbiosis." Over the course of the study, however, 19 articles were omitted because they 1) were written in a language other than English, 2) did not contain a formal in-text citation (e.g., footnote, endnote, parenthetical notation) to "Man-Computer Symbiosis," or 3) were not obtainable (see Appendix A3). As noted in Appendix A3, the majority of these articles were omitted because they lacked clear in-text citations to Licklider's article. In discussing the situation with the coders, it was decided that trying to identify authors' use of "Man-Computer Symbiosis" in the absence of clear indicators (e.g., footnotes, parenthetical notation, specific naming of Licklider and/or the article) was an exercise in guessing that would likely weaken the study and compromise reliability, and so we preferred to err on the side of caution. Based on these omissions, the final data set contained 110 articles.

Intercoder Reliability

Before data obtained by quantitative content analysis may be considered for statistical analyses, it must first be determined if the coding produced data that are reliable according to the standards set in the study. To make this determination, intercoder reliability was calculated in the form of simple percentages of agreement and, in cases where a variable had a finite set of options from which to select, corrections for chance agreement were calculated. In this study, the minimum acceptable level for the manifest article variables was set at 85% simple agreement (with a ± 5% confidence interval to produce the minimum 80% level) or .80 when corrected for chance. For the more latent idea variables, correction for chance agreement was set at .75. Of the reliability tests available, Scott's pi was used to correct for chance agreement given its relatively straightforward calculation in comparison to Krippendorff's alpha and its ability to over-correct less than Cohen's kappa (Potter & Levine-Donnerstein, 1999, see also for a discussion on using Scott's pi when there are more than two coders).

Phase I: Citation Identification Coding

A pilot study was conducted on 67 articles to test the coding instructions used to identify citations to "Man-Computer Symbiosis" in the article set produced by the ISI cited reference search (see Appendix A2). Simple percentage of agreement among the three coders was 87% (± 5%), which exceeded the minimum acceptable level of 80% set for this study. Six articles were omitted from the study during this phase because they lacked formal in-text citations to Licklider. Having reached an acceptable intercoder reliability level, the pilot study results were admitted into the main study, and the coders proceeded to analyze the remaining 53 articles (between the pilot and main studies, 3 additional articles were omitted by the researcher because they lacked in-text citations). The only modification made to the coding instructions was to reduce the number articles and amount of time spent per coding session from the original 10 articles or 1 hour per session to 5 articles or 30 minutes, whichever occurred first. This modification offset fatigue that the coders experienced during the pilot study.

The main study involved coding the remaining 53 articles that were not in the pilot study. Simple percentage of agreement among the three coders was 93% (± 5%). During this phase of coding an additional 4 articles were omitted from the study. The final set of articles available for the Phase II coding was 110.

Phase II: Article and Idea Variables Coding

A pilot study was conducted on 62 of the 110 articles to test the code book covering general article information and the six ideas addressed in "Man-computer Symbiosis." Simple percentages of agreement were calculated on all variables; where appropriate, Scott's pi was calculated to correct for chance agreement. Acceptable levels of reliability were reached on all variables except for *speed mismatch*, requiring a second pilot study. The intercoder reliability results for the pilot and main studies are summarized in Table 5.1.

Table 5.1
Intecoder Reliability Results for Phase II: Article Information

Coding Session	Author		Author Position		Institutional Affiliation		Year of Publication		Journal Title	
	%	pi	%	pi	%	pi	%	pi	%	pi
Pilot Study (n=62)	100	-	85	.84	86	-	100	-	100	-
Main Study (n=48)	98	-	90	.90	88	-	100	-	100	-

Minimum acceptable levels of intecoder reliability: 80% simple agreement or .80 pi.

Intercoder Reliability Results for Phase II: Ideas Coding

Coding Session	Symbiosis		Speed Mismatch		Memory Hardware		Memory Organization		Language Problem		Input-output Equipment	
	%	pi	%	pi	%	pi	%	pi	%	pi	%	pi
Pilot 1 (n=62)	87	.83	63	.51	97	.96	84	.79	96	.95	88	.84
Pilot 2 (n=62)	92	.89	82	.76	98	.97	91	.88	94	.92	96	.95
Main Study (n=48)	92	.89	90	.87	96	.95	91	.88	97	.96	94	.92

Minimum acceptable levels of intecoder reliability: 80% simple agreement or .75 pi

The following steps took place based on the results of the first pilot test: 1) the article information results reached acceptable levels of intercoder reliability and were accepted into the main study; 2) it was decided to have the team proceed to the remaining 48 articles and to code only the general article information (variables 1 through 5) as this portion of the code book was sufficient to reach acceptable levels of reliability; this would keep the study moving forward, and it would reduce the coders' focus to the six ideas later in the study; 3) a class session was devoted to discussing and clarifying the section of the code book covering the six ideas in "Man-Computer Symbiosis" (variables 6 through 11); 4) the code book section dealing with the six ideas was modified during the week that the team completed coding the general article information; 5) a practice session took place to go over the changes made to the code book with respect to the six ideas; 6) using sampling with replacement, a new sample of 62 articles was drawn from the 110 articles, and a second pilot test was conducted on the six ideas. Given the small number of articles in the study set, it was necessary to use sampling with replacement for the second pilot study. This raises a concern that the coders became familiar with the articles, which falsely elevated reliability. While this can be problematic, it became clear during the team meetings that although the coders recognized certain articles, the number of coding decisions made per article reduced their ability to recall specific decisions from the previous pilot study.

The pilot 2 results for the ideas in the 62 articles reached acceptable levels of intercoder reliability and were admitted into the study (Table 5.1). Given these results, the code book appeared to be working sufficiently and was not modified. The coders proceeded to examine the remaining 48 articles, where the main study results for the general article information and the six idea variables reached acceptable levels of reliability and were admitted into the study.

Primary Data Analyses

The goal of this study is to describe the spread of Licklider's ideas among the influence network, as represented by citing articles, generated by the publication of "Man-Computer Symbiosis." The study does not infer to all influence networks, thus the primary data analyses are descriptive in orientation. The data produced by the citation and quantitative content analysis phases of the study are presented on a variable-by-variable basis. The descriptive statistics for the article variables and the citation variables are as follows:

Article Information

The variables coded for each article included: *author*, *author position*, *institutional affiliation*, *year of publication*, and *journal title*. With the exception of *institutional affiliation*, the citation analysis provided the abovementioned variable information for the citing articles. Coders verified that the information in the citing articles matched the information reported by the citation analysis, making corrections where necessary. In general, the variable information reported by the citation analysis was accurate.

Author

In Table 5.2, the *author* variable results are divided into two parts. The left half of the table provides descriptive information for all 154 authors contained in the 110 articles. This half reveals that the majority of the articles were single authored and that only three authors cited "Man-Computer Symbiosis" in three or more articles. The right half of the table provides information for the 123 unique authors that result from removing duplicate listings for those authors who cited "Man-Computer Symbiosis" multiple times. This second section clarifies the range of citing authors, indicating that 79.9% of the total citing authors are unique individuals. Thus, "Man-Computer Symbiosis" diffused across a wide range of individuals rather than clustering into small, unvaried groups of authors. The right side of the table also indicates that the majority of unique authors' articles contained one citation to "Man-Computer Symbiosis."

Table 5.2
Summary Data for Authors Citing "Man-Computer Symbiosis"

Author					
	Frequency	*Percent*		*Frequency*	*Percent*
Total Authors	154	100	Total Unique Authors	123	79.9
Range of authors/article	1 to 6				
Authors per Article					
	Frequency	*Percent*		*Frequency*	*Percent*
1 author	108	69.9	1 citation	101	82.1
2 authors	31	20.3	2 citations	16	13.1
3+ authors	15	9.8	3 citations	3	2.4
			4 citations	3	2.4
Total	154	100	*Total*	123	100
Most Frequently Citing Authors (3+ articles each)					
Brian R. Gaines					
Larry Press					
William B. Rouse					

Author Position

Author position was coded into one of five categories: 1) *Academy*, 2) *Private sector*, 3) *Government*, 4) *Other* (e.g., to include jointly held positions), and 5) *Not specified/unclear*. As Table 5.3 illustrates, the majority of authors held academic positions, followed by authors in private sector and government posts. A few of the authors held joint positions (e.g., academic and private sector), as indicated by the "Other" category. The remainder primarily held positions that were not specified in the article, although some were unclear based on the article reporting and/or coding scheme.

Table 5.3
Summary Results for Author Position

Author Position		
	Frequency	*Percent*
Academy	96	62.4
Private Sector	35	22.7
Government	6	3.9
Other	3	1.9
Not specified/unclear	14	9.1
Total	154	100

Table 5.4
Distribution of Author Position according to Author Order

Author Order by Author Position					
	Frequency	*Percent*		*Frequency*	*Percent*
1st Author/Academy	71	64.5	3rd Author/Academy	3	42.9
1st Author/Private Sector	24	21.8	3rd Author/Private Sector	3	42.9
1st Author/Other	15	13.7	3rd Author/Other	1	14.2
Total	110	100	*Total*	7	100
2nd Author/Academy	21	63.6	4th Author Total	2	
2nd Author/Private Sector	8	24.2	5th Author Total	1	
2nd Author/Other	4	12.2	6th Author Total	1	
Total	33	100	*Total*	4	
			Grand Total	154	

Note: The Author/Other category in this table combines data for the Government, Other, and Not specified/unclear categories given their comparatively low counts.

More specifically, Table 5.4 illustrates that the majority of first authors and second authors held academic positions, followed in frequency by first and second private sector authors. At the level of third author, academic and private sector authors are represented equally. At the level of fourth, fifth, and sixth author, the total number of authors is too small to provide a meaningful detailed breakdown, particularly because these authors fall primarily into the *not specified/unclear* category. Thus, in keeping with the general results in Table 5.3, we see more specifically that academicians held higher author positions more often than other authors.

Institutional Affiliation

Authors' institutional affiliation spanned 88 different organizations. The most frequently represented institutions (Table 5.5) included the University of Illinois, Bolt, Beranek, & Newman, Bell Labs, Texas Tech University, and the University of Maryland for a total of 34.1% of all institutions. Examples of other universities represented in articles citing "Man-Computer Symbiosis" included: Johns Hopkins University, Massachusetts Institute of Technology, Purdue University, and Stanford University. Examples of additional private sector organizations represented: General Electric, Intel Corporation, Microsoft Corporation, Rand Corporation, Sylvania Electronics, and Union Carbide. Examples of government organizations include: U.S.

Table 5.5
Most Frequently Represented Institutions

Institutional Affiliation		
	Frequency	*Percent*
University of Illinois	8	9.1
Bolt, Beranek & Newman	7	7.9
Bell Laboratories	6	6.8
Texas Tech University	5	5.7
University of Maryland	4	4.5
Subtotal	30	34.1
Remaining Institutions (< 3 articles)	58	65.9
Total	88	100

Department of Defense, National Science Foundation, and Oakridge National Laboratory. These results signify a widespread rather than a concentrated diffusion of “Man-Computer Symbiosis” across institutions and institution types.

Year of Publication

Analysis of the publication year for each article revealed fairly consistent citing of Licklider between 1961 and 2001, with a range of 0 to 6 citing articles per year (see Figure 5.1). As predicted by Rogers & Dearing (1993), a lag time of one year occurred between the publication of “Man-Computer Symbiosis” and the publication of the first citing article. The average number of citations per year equaled 2.8. Peak citation years included 1961, which corresponds with the first year following the publication of “Man-Computer Symbiosis,” 1968,

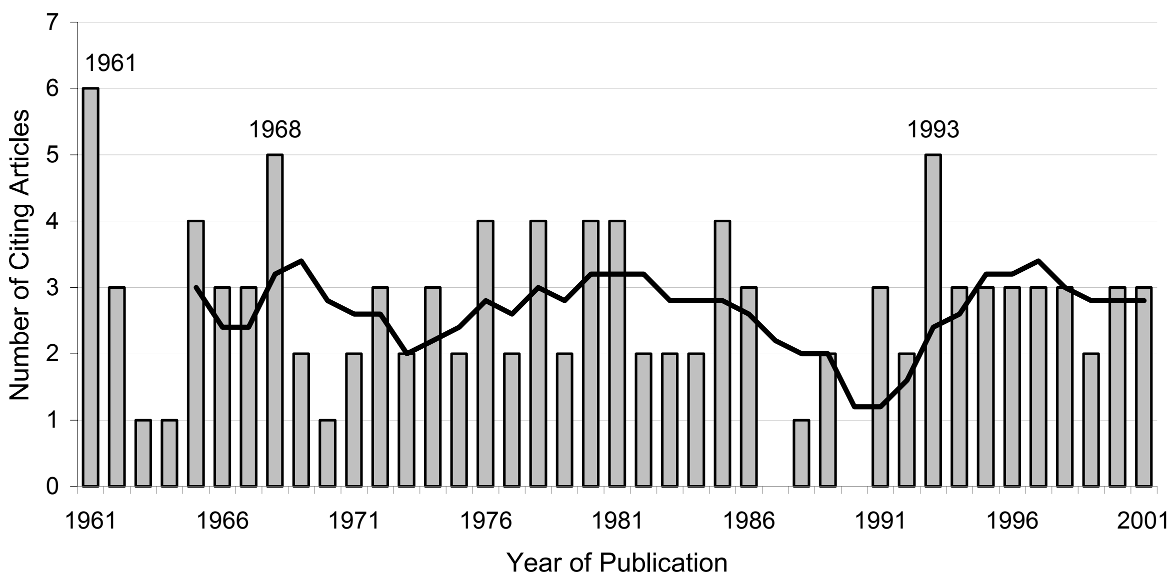


Figure 5.1. Articles (N=110) citing “Man-Computer Symbiosis” by year of publication. The solid line represents a moving averages trendline computed at five-year intervals.

which corresponds with the publication of "The Computer as a Communication Device" (Licklider & Taylor, 1968), and 1993, which corresponds with the year following Licklider's death in 1992 and increased press coverage of the Clinton Administration's focus on the Information Superhighway (Pavlik, 1998).

Citation analysis frequently examines the "rate of decay" for citations over time as a measure of, in this case, a work's general influence. In the sciences, it is not uncommon for the use of a scientific work to decrease exponentially with age (Dieks & Chang, 1976). Published works are also subject to the "dilution effect." This effect refers to the reduced chances for a published work to be cited over time given that in addition to competing with existing works, it must also compete with newly published works in an ever increasing pool of publications. In the case of "Man-computer Symbiosis," Figure 5.1 illustrates that an exponential rate of decay has not occurred over the examined 40-year period (for a similar representation, see Ruff, 1979). Additionally, the dilution effect is not evident. These observations are supported by the moving averages trendline (Figure 5.1), calculated at five year intervals, which shows that the average

Table 5.6
Distribution of Citing Articles by Decade, 1960 – 1990

	Articles Citing "Man-computer Symbiosis	
	Frequency	*Percent*
1960s	28	26.9
1970s	25	24.0
1980s	24	23.1
1990s	27	26.0
Total	104	100
Mean	26.0	

Note: The 2000s are excluded because only 2000-2001 (6 articles) is represented.

number of citing articles overall has remained steady at the starting and ending points of the examined timeframe. The total number of citing articles published per full decade (i.e., 1960s - 1990s) further demonstrates this consistency in citation over time (Table 5.6), despite the increase in publications during the 40-year timeframe from which citing authors could choose.

Journal Title

Journal titles containing the 110 articles citing Licklider spanned 62 unique titles. This number accounts for journal title changes that occur over time (e.g., *Proceedings of the Institute of Radio Engineers*-IRE changed titles in 1963 and is currently known as *Proceedings of the Institute of Electrical and Electronics Engineers*-IEEE). Journals that underwent title changes were counted as one title. Table 5.7 presents the top five journals that contain slightly more than half (56.5%) of the total citing articles. In this case, a concentration in publication outlets is observed.

Table 5.7
Journal Titles in which Citing Articles are Most Frequently Published

Top Five Journals	*Frequency*	*Percent*
International Journal of Human-computer Studies	11	17.7
Human Factors	8	12.9
Proceedings of the IEEE	6	9.7
Communications of the ACM	5	8.1
IEEE Transactions on Systems, Man, and Cybernetics	5	8.1
Subtotal	35	56.5
Remaining Journal Titles	27	43.5
Total	62	100

Citation Information

Within each article, the variables coded for the formal in-text citations to the six ideas contained in "Man-Computer Symbiosis" included: *symbiosis*, *speed mismatch*, *memory organization*, *memory hardware*, *the language problem*, and *input/output equipment*. The 110 articles coded for in-text citations to "Man-Computer Symbiosis" contained 132 citations, equivalent to an average of 1.2 citations per article. Citations to "Man-Computer Symbiosis" ranged from 1 to 4 per article. A citation could contain multiple ideas. Table 5.8 shows that among the six ideas coded *symbiosis* was most frequently cited, followed by *speed mismatch*, *input/output equipment*, *the language problem*, *memory organization*, and *memory hardware*.

Articles containing 1 to 2 citations to "Man-computer Symbiosis' referred to some combination of all six ideas; however, articles containing 3 or more citations to "Man-Computer Symbiosis" only contained references to *symbiosis* in the third and fourth citations. Table 5.8 also illustrates the overall hierarchy in citations to the six ideas across the articles examined while Figure 5.2 depicts the average number of citations per five-year increment for the six ideas. Four articles (3.6%) contained a citation in which all six of the ideas coded for were absent.

Table 5.8
Hierarchy of Citations to Ideas Contained in "Man-Computer Symbiosis"

		In-text Citations to Ideas in "Man-Computer Symbiosis"			
Level	Idea	*Frequency*	*% of Ideas*	*% of Citations*	*% of Articles*
1	*Symbiosis*	114	52.5	86.3	103.6
2	*Speed Mismatch*	41	18.9	31.2	37.2
3	*Input/out Equipment*	20	9.2	15.1	18.2
	Language Problem	18	8.3	13.6	16.4
4	*Memory Organization*	13	6.0	9.8	11.8
	Memory Hardware	11	5.1	8.3	10.0
	Total Ideas Cited	217	100	164.3	197.2

Note: % of Citations and Articles columns sum to >100 due to the possibility for multiple ideas (N=217) to be cited in each citation (N=132) and for each article (N=110) to contain multiple citations. Level 1 = most frequently cited; Level 4 = least frequently cited.

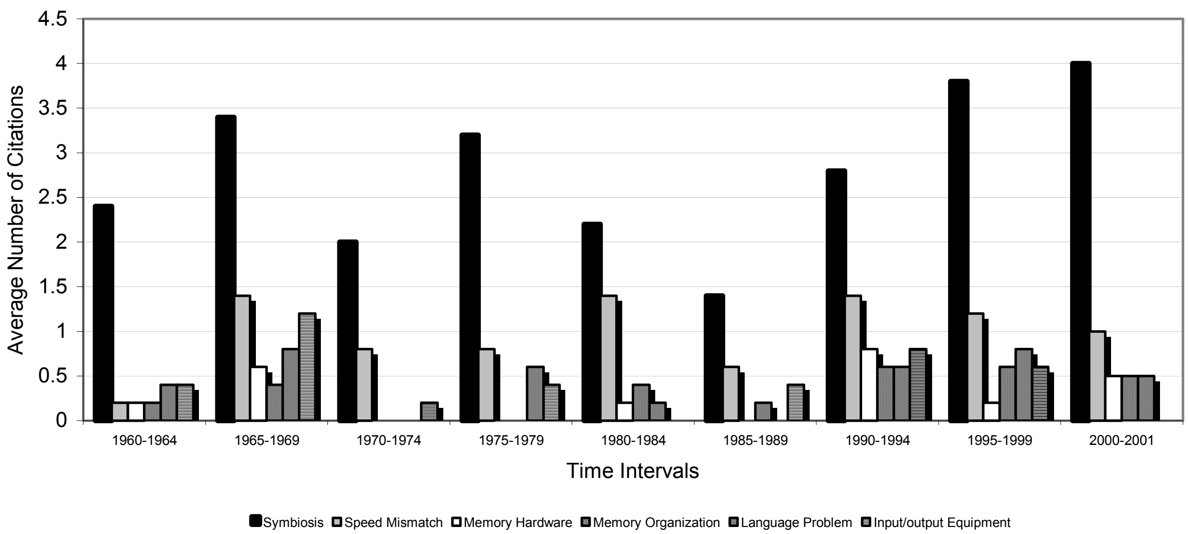


Figure 5.2
Average number of citations to Licklider's six ideas per five-year increment
(Note: 2000-2001 calculated on a two-year average).

Combined, these depictions reveal that not only was *symbiosis* the most frequently cited idea overall, across time it was consistently cited more often than the other five ideas. Between 1995 and 2001, citations to *symbiosis* increased slightly overall.

Secondary Data Analyses

Results from the initial citation and content analyses prompted three follow-up analyses, conducted independently by the author to examine further the reach and influence of "Man-computer Symbiosis." These analyses included examining: 1) journal subject areas using the Library of Congress (LOC) subject classification system, 2) article subject areas using title keyword groupings, and 3) positions of citations to Licklider within each article using the categories of introduction, theory/literature/historical context, methods/results, and discussion/conclusion sections. The results from each analysis are presented below.

Journal Subject Areas

Originally, this study intended to collect data about authors' disciplinary affiliations (e.g., colleges or departments of computer science, psychology, history); however, the citing articles did not supply this information consistently enough to produce a useful set of information. Alternatively, journal subject area was used to approximate author discipline based on the reasoning that authors tend to publish in journals that align with their research areas and disciplines. The 62 journal titles containing the citing articles were analyzed using the longstanding Library of Congress (LOC) subject classification system to provide information about the diffusion of "Man-Computer Symbiosis" within and across disciplines. Founded in 1800, the Library of Congress serves the U.S. Congress, the American public, and the international community. Its collections and subject classification system are highly regarded worldwide (Library of Congress, 2003). This method for collecting information about the spread of "Man-Computer Symbiosis" by discipline was preferred over using the student coders for two reasons: 1) training coders to classify journals into subject areas would likely result in low intercoder reliability because this task requires a degree of expertise not held by the students, and 2) the Library of Congress has a well established and well respected system for subject classification that is consistently applied to all materials, thus coding for journal subject in the content analysis phase would have been redundant and unnecessary.

Table 5.9
Distribution of Citing Articles by Journal Subject Areas

	LOC Subject Classification	*Frequency*	*Percent*
Humanities and Social Sciences	Geography, Anthropology & Recreation *Subclasses*: Anthropology. Culture and cultural processes.	3	2.7
	History: America *Subclass*: History. United States. General.	1	0.9
	Language & Literature *Subclasses*: Communication. Mass Media. Literature.	3	2.7
	Philosophy, Psychology & Religion *Subclasses*: Philosophy. Modern. Speculative philosophy. Ontology. Psychology. Experimental psychology. Gestalt psychology.	6	5.5
	Social Sciences *Subclasses*: Economic theory. Demography. Industries. Land use. Labor. Management. Industrial management. Social history and conditions. Social problems. Sociology. General.	6	5.5
		Subtotal: 19	*Subtotal*: 17.3
Science and Technology	Bibliography, Library Science & Information Resources *Subclasses*: General bibliography. Machine methods of information retrieval. Mechanized bibliographic control.	6	5.5
	Medicine *Subclasses*: Industrial medicine. Industrial hygiene. Medical physics. Medical radiology. Nuclear medicine. Ophthalmology.	1	0.9
	Military Science *Subclass*: Military engineering.	1	0.9
	Science *Subclasses*: Mathematics. Analysis. Mathematics. Electronic computers. Computer science. Probabilities. Mathematical statistics. Science. Cybernetics. Science. General.	30	27.3
	Technology *Subclasses*: Aeronautics. Aeronautical engineering. Computer engineering. Computer hardware. Electrical engineering. Electronics. Engineering. *e.g.,* Human. Industrial. Mechanical. Nuclear. Systems. Manufactures. Production management. Operations management. Technology. Telecommunication.	53	48.2
		Subtotal: 91	*Subtotal*: 82.7
	Total	110	100

Note: The subclass listings represent the specific subject areas of the journals in which citing articles were published.

To locate and record a journal title's corresponding LOC call number, each title was searched in the LOC online catalog, accessed at http://catalog.loc.gov/. The resulting call numbers were subsequently located in the LOC classification outlines, available at http://lcweb.loc.gov/catdir/cpso/lcco/lcco.html, to provide general and subclass subject areas for each journal. Articles citing "Man-Computer Symbiosis" were published in journals spanning ten general subject areas and numerous subclass subject areas, as shown in Table 5.9. However, reducing the LOC subject areas into two broad categories, 1) *humanities/social sciences* and 2) *science/technology*, revealed that articles published in *science/technology* journals were in the majority (82.7%). Accordingly, we see a concentrated spread of "Man-Computer Symbiosis" by discipline, as represented by journals' general and subclass subject areas.

Article Subject Areas

The ISI cited reference search results for "Man-Computer Symbiosis" provided the complete title for each citing article. Keywords and phrases (e.g., time-sharing, task allocation) from each citing article title were examined to ascertain the general subject areas of the 110 articles in the study. This analysis provided general information about the extent to which the topical areas of the citing articles aligned with the six ideas proposed by Licklider, an indicator of his research agenda's reach. Figure 5.3 lists examples of article title keywords and phrases appearing in each decade from 1960 onward. Similar to the preceding journal title subject analysis, the article subject areas largely resided in the general area of science and technology. Within this broad category, article subject areas, such as "time-sharing" and "visual display units," aligned with Licklider's ideas *speed mismatch* and *input/output equipment* respectively to demonstrate that his ideas were cited in papers addressing the specific areas in computer technology that he identified as needing additional research and improvement. Across time, the articles consistently addressed human-computer relationships, time-sharing, ergonomics, interface navigation, and communication topics using a variety of methodologies including experiments, surveys, case studies, historical analyses, and critical analyses.

Position of Citations

Lastly, citing articles were examined for the placement of each in-text citation. Citation location functions as an indicator of how the Licklider's article diffused in use within citing articles (e.g., to support theory, provide historical context). Article section headings were used to identify the primary application of Licklider's article in the citing works. Citation location was placed into one of four categories: 1) *introduction*, used to broadly present the article topic, 2) *theory/literature/historical context*, used to set up the theoretical framework, to support a review of the literature, and/or to provide an historical context or foundation for an argument for the citing article, 3) *methods/results*, used to directly apply to the main purpose of the article by appearing in procedures, methods or results sections, or 4) *discussion/conclusion*, used to frame the interpretation of study results or to support the overall conclusions of the article. These

	Article Title Keywords and Phrases			*# of Articles*
1960s	automated info systems automatic speech recognition chord keyboard communication complex systems	computer display design computer graphic terminals data handling ergonomics experimental study human frequency response lightpen controlled program	man computer interaction online data analysis psychological purposive systems time-sharing visual feedback delay	28
1970s	adaptive allocation batch processing conditions behavior communication modes complex systems computer cooperative problem solving	data processing systems display requirements ergonomics experimental analysis heuristic problem solving human computer interaction interactive scheduling management info systems	man computer interfaces man machine symbiosis multitask situations online interactive systems psychological search intermediary survey task components	25
1980s	5th generation computing calculator chalkboards comparative evaluation computer response time computer revolution data entry data representation dialog based communication	ergonomics experimental study history/historical perspective human computer interaction information retrieval interactive computer dialog keyboards machine aided intelligence	management decision systems psychological aspects online personal construct systems task allocation time-sharing touch input devices visual display terminals	24
1990s	allocation case study/case history cognitive coupling collaborative systems collective monologues communication computer/computing cyberspace	formalization techniques history intelligence augmentation interactive computing Internet joint cognitive systems knowledge exchange architecture	man computer symbiosis multiagent systems networks personal computer/computing time-sharing virtual reality visual display units	27
2000s*	adaptive computing allocation borg/cyborg	browsing cars communication	digital library proactive computing ubiquitous computing	6
			Total Articles	110

* Data for the 2000s are limited to the years 2000-2001.

Figure 5.3
Distribution by decade of citing article subject areas using title keyword and phrase examples.

categories are based on the common hour-glass structure of articles, as outlined in the 5th edition Publication Manual of the American Psychological Association, whereby the introduction sets up the broad scope of the article, the theoretical/contextual framework begins to narrow the focus to the topic of study, the procedures/methods/results focus specifically on the topic, and the discussion/conclusion sections broaden the topic to place the findings in a larger context. Table 5.5 shows the distribution of the 132 citations across the four location categories. The majority of articles (85.6%) cite "Man-Computer Symbiosis" in the introductory and theoretical/historical context sections; however, this particular set of results should be interpreted with some caution because other content coders did not independently verify these findings.

Table 5.10
Location of In-text Citations within Citing Articles

Location of In-text Citations	Distribution of In-text Citations		
	Frequency	*% of Citations*	*% of Articles*
Introduction	32	24.2	29.0
Theory/Literature/Historical context	81	61.4	73.6
Methods/Results	6	4.6	5.5
Discussion/Conclusion	13	9.8	11.8
Total Citations	132	100	119.9

Tests for Independence and Co-variation

The preceding results prompted three additional analyses that investigated possible differences and co-variations between certain sets of variables. The first analysis asked:

1. Did authors publishing in the *humanities/social sciences* cite the six ideas in "Man-Computer Symbiosis" differently than authors publishing in *science/technology* journals?

This analysis examined the differences in the diffusion patterns of Licklider's ideas among citing authors and also examined differences in the salience of agenda items set forth by Licklider. Chi-square analyses were conducted to address this question. To provide sufficient data for the analysis, the journal subject categories were collapsed from the original 10 Library of Congress subject classifications into two broad categories *humanities/social sciences* and *science/technology*. The decision to divide journal subjects into these two broad categories was based on a combination of professional work experience in an academic research library and best practices. Generally speaking, humanities and social sciences are closely related, and difficult to separate from one another. A similar dynamic holds with the areas of science and technology.

However, it is easier to separate the humanities and social sciences from the "hard" sciences and technology areas given a predominant, if not exclusive, focus on the scientific method by science and technology researchers. To illustrate, the Communication discipline contains elements of both the humanities (e.g., rhetoric, critical/cultural analysis) and the social sciences (e.g., mass media effects) depending on a researcher's area of focus, making it difficult to clearly separate the field into two distinct camps. The Library of Congress classifies a number of communication journals into the humanities subject area of Language and Literature, even though some social scientific communication scholars would disagree with this placement. However, a few Communication journals (e.g., Journal of Broadcast and Electronic Media) are classified in the science and technology areas because they focus on technological aspects of communication media infrastructures. It is, perhaps, much easier to state that chemistry and engineering are much less likely to branch into the humanities and social sciences to any great extent. Obviously, the separation of subject areas into two broad categories is an approximation at best and relies on general tendencies of disciplines to align themselves more with one broad category than another.

Although some articles contained more than one citation to "Man-Computer Symbiosis," chi-square analyses were conducted only on the articles' first citation to each of the six ideas in order to maintain independence of observations, a basic test requirement (Siegel & Castellan, 1988). In every case for the six ideas tested, the chi-square analysis revealed that authors publishing in the *humanities/social sciences* did not differ from authors publishing in *science/technology* journals with respect to the ideas they cited. Thus the citation patterns presented in Figure 5.2 and Table 5.8 were shared equally between the two groups despite the fact that articles published in *science/technology* journals were the dominant group by an approximate factor of 5.

The second analysis stemmed from the question:

2. Did authors publishing in the *humanities/social sciences* locate their citations to "Man-Computer Symbiosis" differently in their articles than authors publishing in *science/technology* journals?

This analysis examined possible differences in the use of Licklider's ideas based on location of the citation and where an author published. Use of Licklider's ideas, as represented by citation placement, relates to understanding how his research agenda was incorporated into other's work, and if that incorporation varied by the journal subject area. As with the preceding analysis, a chi-square test was conducted on the first citation to each article. The analysis revealed no differences between where an author published and where the citations were located in the articles. In Table 5.10, authors publishing in *humanities/social sciences* journals were just as likely as authors publishing in *science/technology* journals to locate the majority of their citations to Licklider in the introductory and theory/context sections. Thus Licklider's research agenda was applied consistently across disciplines.

The last analysis examined how the six ideas contained in the citations to "Man-Computer Symbiosis" co-varied with one another.

3. Given that *symbiosis* was the most frequently cited idea, how likely were authors citing *symbiosis* to also cite: *speed mismatch*, *memory hardware*, *memory organization*, *language problem*, and *input/output equipment*?

This question takes a closer look at citation patterns among the ideas themselves to further examine the diffusion of specific ideas among citing authors and to further reveal the nature of the agenda set among these authors. To investigate this question, odds ratio analyses were conducted to examine the likelihood of pairs of ideas being cited together. Odds ratio analysis identifies the extent to which two variables co-vary or are related to one another (Bohrnstedt & Knoke, 1994). An odds ratio of 1.0 indicates that the two variables are identical and, thus unrelated. An odds ratio greater than 1.0 reveals a positive co-variation of the variables (i.e., the upper category of the variables tends to be associated), while an odds ratio less than 1.0 indicates negative or inverse co-variation (i.e., the upper category of one variable tends to be associated with the lower category of the other). The results of these analyses, presented in Table 5.11, reveal that when *symbiosis* was cited, it was frequently cited alone; however, when the remaining five ideas were cited, they were frequently cited in combination with one another.

Table 5.11
Citation Co-occurrence among Idea Variables

	Symbiosis	Speed Mismatch	Input/output Equipment	Language Problem	Memory Organization	Memory Hardware
Symbiosis	--					
Speed Mismatch	.71	--				
Input/output Equipment	1.0	2.5	--			
Language Problem	2.1	2.5	13.3	--		
Memory Organization	1.5	5.3	5.5	10.2	--	
Memory Hardware	NC	10.9	12.7	9.6	27.1	--

This table is read as follows: Authors citing *symbiosis* are 0.71 times as likely to also cite *speed mismatch*. Authors citing *speed mismatch* are 10.9 times more likely to also cite *memory hardware*.

NC = not calculable

Chapter Summary

This chapter presents the results of the data analyses conducted on the 110 articles citing "Man-Computer Symbiosis" between 1961 and 2001. Overall, the results of the study indicate that *symbiosis* was the dominant (52.5%) idea cited among all six ideas—across disciplines and over time. Additionally, when *symbiosis* was cited it was frequently cited alone, and when the other five ideas were present they were frequently cited in combination with one another. The majority of the citing authors (62.3%) were affiliated with academic institutions and the articles were published primarily in science and technology journals (82.7% combined). Authors publishing in humanities and social sciences journals did not differ in their citations to the six ideas from those publishing in science and technology journals. Excepting the years 1987 and 1990, "Man-Computer Symbiosis" has been cited in 1 to 6 articles annually over a 40-year period for an average of 2.8 citing articles per year. By decade, the average number of articles citing "Man-Computer Symbiosis" is relatively stable at 26 (range = 24 to 27).

Within these articles, "Man-Computer Symbiosis" was cited between 1 and 4 times for an average of 1.2 citations per article. The majority of articles (85.6%) cited Licklider in the introduction and theory/historical context sections. The citing articles covered a range of topics, primarily in the area of *science/technology*, consistently addressing subjects related to human-computer interactions, time-sharing, ergonomics, and communication. A variety of methodologies were applied in these investigations including experiments, surveys, case studies, historical analyses, and critical analyses to test and to predict developments in computer technology as well as to assess current and future psychological and social effects of technological advances in computing. The next chapter discusses the implications of these results within the context of the study goals, the research questions asked, and the guiding theoretical and methodological frameworks.

CHAPTER SIX

DISCUSSION

The goal of this study is to trace and describe the spread and influence of "Man-Computer Symbiosis" among citing articles published from 1960 – 2001. The study is guided by diffusions of innovations and supplemented by the agenda-setting function to trace this spread and influence. Citation analysis and quantitative content analysis are the methods used to collect the data to describe this spread and influence. This chapter discusses the results of the study within the contexts of the study goals, the research questions asked, and the theoretical and methodological frameworks applied. The primary objective of this chapter is to provide interpretations of the data and to consider the implications of the results regarding the contributions of "Man-Computer Symbiosis" with respect to its spread and influence among the authors citing the article and claims concerning the research agenda set forth in the article by Licklider.

Study Goals, Research Questions, and General Results

As detailed in the Introduction, the design of this study addresses three main goals occurring on the substantive, theoretical, and methodological levels. On the substantive level, this study seeks to improve our understanding about the perceived importance of "Man-Computer Symbiosis" by examining its role in disseminating ideas for a new way of interacting with computers as communication and information tools. On a theoretical level, this study seeks to expand the application of diffusion of innovations within the communication discipline from one linked primarily to innovative devices (e.g., cell phones, satellite radio, online newspapers) to one that examines the realm of innovative ideas. With respect to the agenda-setting function, this study also seeks to expand its application from one typically focused on the framing of news stories to one examining the publication and framing of a research agenda. Lastly, on the methodological level, previous studies examining the influence of authors and their works have combined citation analysis and *qualitative* content analysis, whereas this study combines citation analysis and *quantitative* content analysis to produce a set of results from which claims about patterns in citations over time rest on a stronger empirically defensible foundation. Each goal is addressed in turn.

Substantive Contributions

Internet histories, oral histories, and communication texts are examples of sources that frequently cite "Man-Computer Symbiosis" as a watershed article that predicted the evolution of networked computing and that helped to develop today's Internet. These texts rely largely upon historical analyses in the form of in-depth interviews and author opinion to ascertain the importance of Licklider's 1960 publication. This study expands upon previous research by analyzing the influence network generated by authors incorporating Licklider's ideas into their own works as a means to offer an additional perspective on the spread of his ideas for improving the human-computer relationship among other researchers. More specifically, the study examines the in-text citations to reveal which of Licklider's ideas received credit and patterns in citations to "Man-Computer Symbiosis" over time. In pursuit of these goals, two research questions guided the analysis.

> **RQ1** In Licklider's article, "Man-Computer Symbiosis," what ideas for improving the human-computer relationship were communicated to promote a research agenda for others to consider adopting?

This question is important because we must first identify the proposed research agenda, as represented by the six ideas, contained in "Man-Computer Symbiosis" in order to trace its diffusion among subsequent citing articles. Although addressing this question appears simplistic and straightforward, it was not. Identifying the six ideas contained in "Man-Computer Symbiosis" required repeated careful and sensitive readings of the piece with the goal of representing its content as accurately as possible. To further ensure an accurate reading of the article, students participating in the data collection phase of the study provided independent summaries of their interpretations of the article's main points. In turn, these readings were discussed among all research team members to identify the variables that were coded in the content analysis. Additionally, as reported in the methods chapter, the code book for the content analysis was based primarily on the organization and the wording of the article in an effort to accurately reflect its content.

Licklider's 1960 article, "Man-Computer Symbiosis" (detailed in Chapter Two) contained an outline for six main ideas that were divided into a hierarchical agenda containing two levels. On the overarching conceptual level, Licklider detailed the goal of achieving an improved relationship between humans and computers. The strengths of humans were balanced with those of the computer, forming a cooperative partnership to promote increased higher-level thinking and complex problem solving. Licklider used the term *symbiosis* to describe the essence of this relationship.

To achieve this symbiotic relationship, on a concrete, secondary level, Licklider identified specific areas in computer technology that needed improvement before such a relationship could exist. These five areas included improvements to 1) information processing differences between humans and computers or what Licklider termed the *speed mismatch between men and computers*, 2) data storage media and types of memory or *memory hardware*, 3) file structures and data access or *memory organization*, 4) differences in human communication styles and computer communication styles or *the language problem*, and 5) the physical devices by which humans and computers interact or *input/output equipment*.

In this study, these two levels containing six ideas are taken as the basic research agenda set forth in the article. The ideas and the hierarchy in which Licklider expressed them are summarized as:

Level I: Overarching idea presented in "Man-Computer Symbiosis"

Symbiosis

Level II: Subordinate ideas concerning the need for technological advancements in computing to address the following:

Speed mismatch

Memory hardware

Memory organization

The language problem

Input/output equipment

The second research question examines the extent to which the six ideas specified in Licklider's agenda diffused among individuals citing "Man-computer Symbiosis."

RQ2 Among the authors citing "Man-Computer Symbiosis," what do the frequencies and patterns in citation to Licklider's ideas reveal about the article's spread and influence among these individuals?

To address this question, citation analysis identified the network of authors citing "Man-Computer Symbiosis" between the years 1960 and 2001. The formal in-text citations to Licklider within articles meeting the study objectives were then quantitatively content analyzed using independent coders to identify 1) the characteristics of the authors and the articles and 2) to identify which of Licklider's ideas diffused among these authors. On the surface, the results of the study indicate that *symbiosis* was the dominant (52.5%) idea cited among all ideas and comprised 86.3% of all citations contained in the 110 articles examined. The majority of the authors (62.3%) were affiliated with academic institutions and the articles were published primarily in science and technology journals (82.7% combined). With the exception of two years, 1987 and 1990, "Man-Computer Symbiosis" was cited in 1 to 6 articles annually over a 40-year period for an average of 2.8 citing articles per year. Within these articles, "Man-Computer Symbiosis" was cited between 1 and 4 times for an average of 1.2 citations per article. Three follow up analyses conducted by the researcher indicated that 1) with respect to the ideas cited, authors publishing in the *humanities/social sciences* did not differ from authors publishing in *science/technology* outlets, 2) the citing articles addressed a range of topics that were related to the six areas outlined in "Man-Computer Symbiosis" and 3) within these articles, the majority of citations to Licklider occurred within the introductory and theoretical/historical sections. This information alone, while valuable in providing an overall picture of the citation network, lacks an explanatory component. To provide deeper insight into these results, diffusion of innovations and the agenda-setting function are applied to guide the interpretations of these results.

Characteristics of the Influence Network Over Time

Diffusion of innovations examines the spread of an innovation via communication channels among members of a social group over time. In Licklider's article, the innovation was his idea for redefining the human-computer relationship or man-computer *symbiosis* and the ideas related to improving five areas of computer technology. The communication channel was the scholarly journal, *IRE Transactions on Human Factors in Electronics*, in which "Man-Computer Symbiosis" was published in the year 1960. The social system into which the idea for symbiosis was introduced is comprised primarily of career and academic researchers whose works are indexed in the Institute for Scientific Information citation indexes. The timeframe for the investigation covers the years 1960–2001.

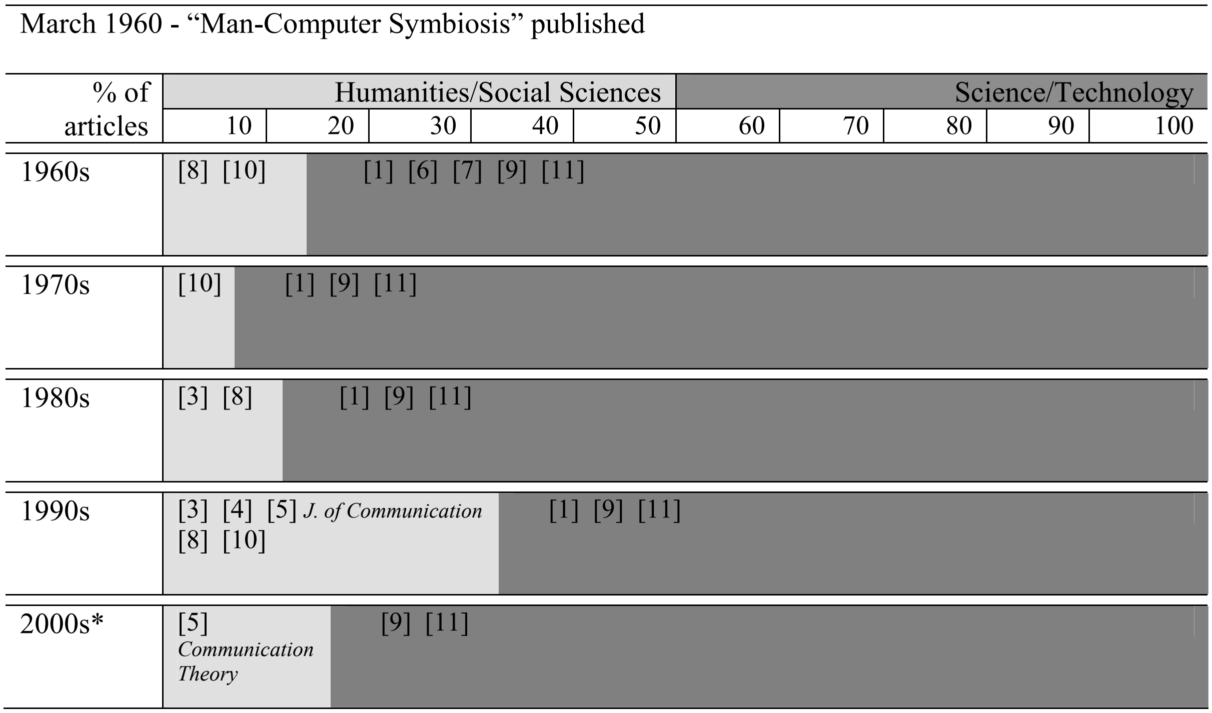
Social systems are comprised of individuals who form networks possessing certain general characteristics. The characteristics of these networks influence an innovation's rate of spread and breadth of reach. Diffusion outlines two broad types of networks: homophilous and heterophilous. Homophilous networks contain individuals who are similar in certain attributes such as education, occupation, income, beliefs, etc. In contrast, heterophilous networks include members who are dissimilar in these attributes. Homophilous networks occur frequently because they generally foster more effective communication than heterophilous networks and are more likely to form naturally given the common ground shared by the members. An innovation tends diffuse more rapidly in a homophilous network due to the similarities of the members and their interconnectedness to one another; however, the spread of the innovation is usually limited to the members of that network. In the case of heterophilous networks, an innovation tends to diffuse slowly, but, if successful, its spread may be more far reaching than in homophilous networks given a tendency for their members to have links with individuals in other networks.

In the case of "Man-computer Symbiosis," at the most general level, the citation network identified in this study is predominantly homophilous in that the members of the examined social system are primarily career and academic researchers. More specifically, the results from this study indicate that within this network academicians publish the majority of articles citing Licklider in *science/technology* journals. Based on the characteristics of the scholarly publication community, it is not surprising that the majority of citing authors are academicians given their motivations to publish, in part, for the purpose of securing tenure and the role of scholarly journals to publish academic research. Additionally, the ISI citation indexes focus on academic publications, though they do contain some private sector and government oriented publications. At the same time, the citation network for "Man-Computer Symbiosis" contains a respectable number of individuals affiliated with the private sector (22.7%), and this may be due to collaborative research between academic and private sector interests, particularly with respect to funded projects in computing.

Among citing authors and within the journal subject areas, the spread of Licklider's ideas is wide and varied. Of the 154 authors, 123 are unique individuals. This range of authors reveals that while citations to "Man-Computer Symbiosis" are concentrated among academicians in the *science/technology* fields, within this group only a small number of authors (17.9%) cite Licklider multiple times, thus Licklider's ideas spread widely among individual authors in this set.

Within the general *science/technology* subject heading, into which the majority of the citing articles are grouped, the subclass subject headings are quite varied ranging from bibliographic analysis to ophthalmology to engineering (see Table 5.9). As with the authors, while articles citing "Man-Computer Symbiosis" are concentrated in the general area of *science/technology*, we see the article diffusing within these broad categories across a wide range of subclass subject areas. In contrast, the spread of Licklider's ideas to other broad subject categories (i.e., *humanities/social sciences*) is slower. Figure 6.1 illustrates this pattern. Thus within the broad homophilous network of career and academic researchers, there exist at least two sub-heterophilous networks: *humanities/social sciences* and *science/technology*. While both groups are made up of individuals with similar educational backgrounds and motives to research, the sub-specialties of these individuals create barriers to information flow in that, for example, these individuals will tend to focus on certain sets of literatures to the exclusion of others. An individual studying 17^{th} French poetry is not likely to read journals covering astrophysics.

During the three decades after its publication, articles citing "Man-Computer Symbiosis" reside primarily in the general area of *science/technology*. In the 1990s, the number of articles citing Licklider in the *humanities/social sciences* reaches a noticeable high of 33%. If the data for 2000-2001 are any indication, this spread into the *humanities/social sciences* is likely to continue throughout the decade given that in the first two years of the 2000s the number of citing articles appearing in this general subject area (17%) is greater than the total for all of the 1960s (14%) and is slightly more than half the value for the 1990s. With respect to the Communication discipline, we see Licklider's work diffusing into the field during this period of increase as noted by the communication journal titles specified in Figure 6.1; one article was published in the



Journal subject using the Library of Congress classification schedule:
[1] Bibliography, Library Science & Information Resources
[2] Education
[3] Geography, Anthropology & Recreation
[4] History: America
[5] Language & Literature
[6] Medicine
[7] Military Science
[8] Philosophy, Psychology & Religion
[9] Science
[10] Social Sciences
[11] Technology

*Data for the 2000s are incomplete, containing only the years 2000-2001.

Figure 6.1
The "Man-Computer Symbiosis" citation network as illustrated by journal subject area.
Two subject levels include: 1) humanities/social sciences, and science/technology categories and 2) the more specific Library of Congress subject classifications.

Journal of Communication in 1995, and the other article appeared in *Communication Theory* in 2000. With the apparent shift to a heterophilous network in the making, "Man-Computer Symbiosis" may experience increased citations as authors publishing in the *humanities/social sciences* continue to gain awareness of his ideas. As diffusion explains, the increased appearance of citing articles in *humanities/social sciences* journals may be due to the existence of "bridge" articles and/or interpersonal links that are forming between the two networks (Rogers, 2003).

Another explanation for the slow diffusion of "Man-Computer Symbiosis" into the *humanities/social sciences* is one of relevance, which speaks to the innovation attribute termed by diffusion as "relative advantage." During the 1960s and into the 1980s, the idea for man-computer symbiosis likely resonated more strongly among science and technology researchers where computers played an increasingly important role in the research process, both as a tool and a topic for study, than among researchers in the humanities and social scientists where computers by comparison did not yet play as major a role. With the advent and diffusion of personal computers in the mid-1980s followed by the 1994 release of the Internet to the general public in the United States, the relevancy of computer technology both as a tool and an area for research received increased attention in the humanities and social sciences (e.g., in 1996, the winter issue of *Journal of Communication* featured articles addressing the importance of researching the Internet; also see the Newhagen & Rafaeli (1996) article) and we see this pattern illustrated in the preceding figure with increased citations to Licklider by researchers in the *humanities/social sciences*.

Regardless of general subject area into which the citations are grouped, Figures 6.1 and 5.1 illustrate that over time the rate of citation to "Man-Computer Symbiosis" has remained relatively stable, ranging from 28 to 24 citations per decade for an average of 26 articles, and data for the 2000s suggest that this pattern will continue. Given that we do not see an exponential decline in citations to "Man-Computer Symbiosis" or evidence of a dilution effect in the 40-year timeframe examined, it is concluded that the article, now in its fifth decade, is still diffusing into the research community. Further support for this observation is illustrated in Figure 6.2, which plots the cumulative frequency of citations to "Man-Computer Symbiosis" with an accompanying exponential trendline over the 40-year timeframe examined. The cumulative frequency plot line does not yet show signs of flattening out to signal the end of the diffusion cycle.

Interestingly, the graph in Figure 6.2 indicates that the distribution of citing articles over time is more uniform, or flat, than normal, or bell-shaped. Thus the rate of adoption for "Man-Computer Symbiosis" is closer to an exponential shape than a sigmoid shape, which runs counter to the typically portrayed S-shaped diffusion curves. However, uniform distributions do occur in the diffusion process. As Gatignon and Robertson (1985) explain, two general cases affect the diffusion curve. In the first case, "there is a range of initial beliefs with equal probabilities" such that "the adoption potential is depleted at a constant rate" among individuals in the social system (p. 859). This first case produces an exponential diffusion curve. Factors that produce an exponential diffusion curve include: a comparative lack of personal influence, a low-involvement adoption process, low uncertainty, low innovation and switching costs, and a uniform pattern of initial beliefs toward the innovation within the social system. In the second case, “there is a unimodal distribution of initial beliefs around a mean value” to produce a sigmoid (S) diffusion curve. In this case, initial uptake of the innovation is slow, followed by a rapid uptake, and then a tapering off. Factors that contribute to a sigmoid diffusion curve include: personal influence at work in the social system, a learning hierarchy process of adoption, high uncertainty, high innovation and switching costs, and unimodal distribution of initial beliefs within the social system. This second case produces the “S” curve typically associated with diffusion studies.

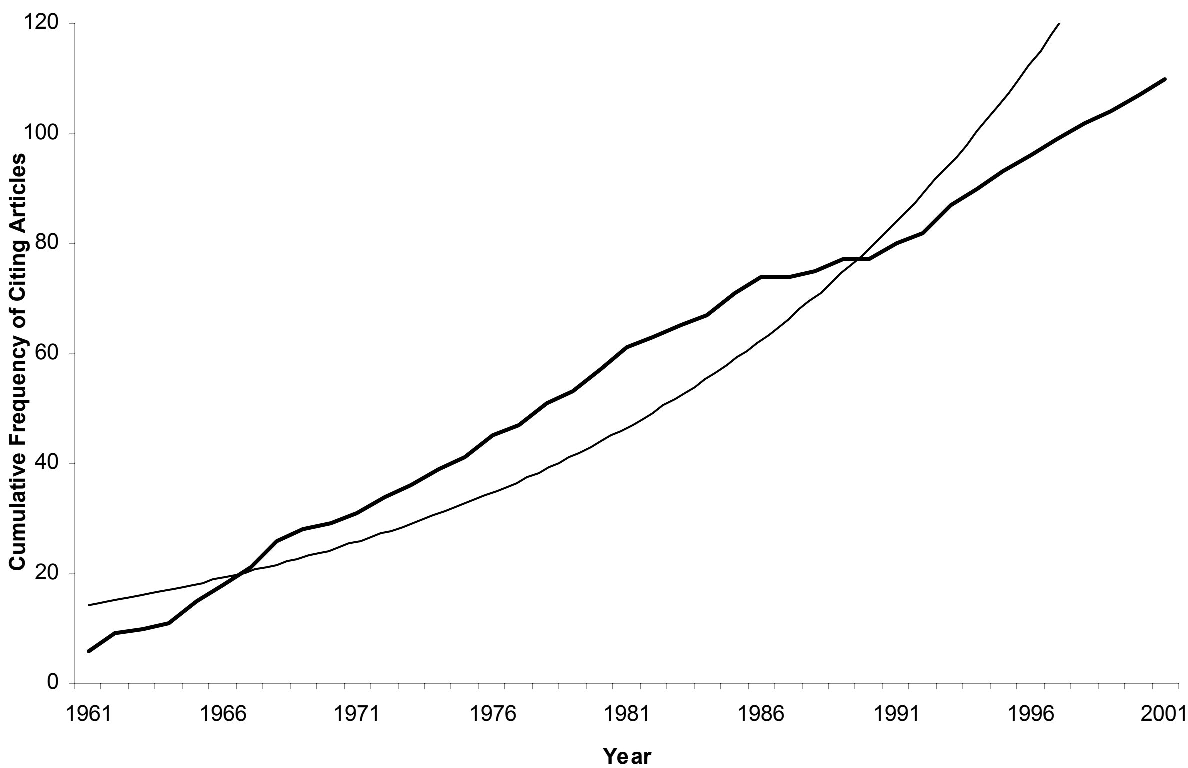


Figure 6.2
Adoption curve for “Man-Computer Symbiosis”

In the case of “Man-Computer Symbiosis,” an exponential diffusion curve better describes the article’s rate of adoption among the examined citing authors than the sigmoid curve. The exponential diffusion curve factors outlined by Gatignon and Robertson (1985) may help to explain this pattern. The first factor concerns a relative lack of interpersonal influence. In the publishing arena, this is likely the case. Authors citing “Man-Computer Symbiosis” interact with the written artifact (i.e., the article) rather than with the author (i.e., Licklider) directly and their works in turn stand in for interpersonal interactions with other citing authors.

The second factor refers to a low-involvement adoption process that is characterized by low learning and limited cognitive processing requirements with respect to the innovation. The ideas presented in “Man-Computer Symbiosis,” though innovative, are fairly straightforward and easy to understand. The article is written at a level general enough for a wide range of individuals to understand.

The third factor deals with low uncertainty. Low uncertainty refers to the amount of information an individual requires to make an adoption decision about the innovation. Again, in the case of “Man-Computer Symbiosis” the general level at which the article is written makes it easy to comprehend. The ease with which readers can understand the article reduces uncertainty about Licklider’s ideas for creating a symbiotic relationship and the steps needed to create such as relationship.

The fourth factor involves low innovation and switching costs. This refers to the expense—monetary, psychological, or otherwise—involved in adopting a particular innovation. A technological innovation requiring the retooling of a factory would be considered to possess high innovation and switching costs both in terms of financial expense and employee retraining. With “Man-Computer Symbiosis” the switch is ideological in nature. Licklider promotes a new vision of the computer, shifting our vision away from the computer as a large calculator to the computer as a collaborator in research and higher order thinking. The cost in embracing this vision is relatively low compared with retooling a factory. Of course certain paradigmatic shifts are more costly than others (Kuhn, 1970). The Copernican revolution is a prime example where the replacement of one line of thinking with another had a dramatic effect on the scientific research community and beyond. In the case of “Man-Computer Symbiosis,” however, while Licklider’s idea for symbiosis was innovative, it came at a time when other researchers were questioning the limited role of computers in society (Waldrop, 2001) making it a less disruptive revolutionary event.

The final factor that produces the exponential diffusion curve is a uniform distribution of initial beliefs about the innovation over time. This pattern is clearly depicted in Figure 5.1 and Table 5.6 where citations to "Man-Computer Symbiosis" remain relatively constant over the 40-year timeframe. This consistency in citation over time produces the relatively straight adoption curve depicted in Figure 6.2.

Lastly, it is also worthwhile to consider two other possible contributors to the article's diffusion curve that are related to the types of potential adopters—innovators, early adopters, early majority, late majority, and laggards—and to the role of journals as influential sources of information. In the case of career and academic researchers, the group examined in this study, these individuals are typically innovators and early adopters in the larger social system in which they reside. That is, researchers by definition strive to be on the "cutting-edge" in their works. Thus what we may be witnessing with respect to the article's diffusion is a truncated version of the larger untold picture. Additionally, the early Ryan and Gross (1943) study revealed that interpersonal channels were more effective at influencing the adoption of an innovation than mass channels of communication. Specifically, the salesmen and neighbors played a larger role in diffusing the hybrid seed corn than did the farm journals. A similar pattern may be occurring with "Man-Computer Symbiosis." The research journal, a channel of mass communication, increases researcher awareness about an innovation, in this case *symbiosis*, but the wider diffusion of the idea may have occurred, and may still be occurring, via informal interpersonal channels (e.g., conversations between colleagues) that are more difficult to assess.

Licklider's Agenda

Agenda-setting is the process by which a particular topic or set of topics is made the focus of attention among members of a social system by an individual or group of individuals who are in the position (e.g., financially, by reputation, access to communication channels) to disseminate the messages. In general, the agenda-setting process has the potential to make certain items salient in the minds of listeners, readers, and viewers of media and to influence how people perceive an issue or think about a topic. Within organizations (or communities), agenda-setting is the first stage in the initiation phase of the innovation process. As Rogers (2003) points out, "Setting the agenda for innovation in an organization is tremendously powerful" (p. 423).

This study combines the traditional view of agenda-setting in the mass media with agenda-setting in the innovation process to provide insight into the influence of "Man-Computer Symbiosis" on a community of citing authors.

One question asked by agenda-setting is, who set the agenda? In the case of this study, Licklider and Elkind set the agenda. In response to a perceived need to rethink and enhance the role of computers in society, based partly on a realization that he spent the majority of his time positioning himself to think, Licklider formulated an innovative idea he termed *man-computer symbiosis*. Licklider shared this vision via informal (e.g., conversations) and formal (e.g., conference presentations and publication) channels. With respect to publication, the focus of this study, Elkind helped to set the agenda by soliciting an article from Licklider that initiated the launch of the *IRE Transactions on Human Factors in Electronics*. Although Elkind did not specify the content of the invited article, he was familiar with Licklider's work (Waldrop, 2001). Elkind wanted the journal to push the boundaries of human factors research, and he knew from his interpersonal contacts with Licklider that he was engaged in such envelope-pushing work. Thus, Elkind, much like a news editor, exercised his gate keeping authority to determine what research was published and what was not based on his own agenda for promoting cutting-edge research. Although Licklider had been promoting his agenda for symbiosis prior to Elkind's invitation, in "Man-Computer Symbiosis" his agenda received a formal and public voice in the research community.

Thus, Licklider set forth a research agenda in "Man-Computer Symbiosis" calling for a new way of defining the human-computer relationship and the technological improvements necessary to realize this relationship. More directly, Licklider told the readers of his article to 1) think about attaining man-computer *symbiosis* and 2) focus attention on improving problem areas related to *speed mismatch*, *memory hardware*, *memory organization*, *the language problem*, and *input/output equipment*. He framed his agenda as a vision that was attainable in the not too distant future (ARPAnet came along nine years later). This research agenda was initially confirmed by independent readings of the thirteen undergraduate students who participated in the study. The citing articles examined by the study subsequently confirmed the research agenda proposed by Licklider. Only 3.6% of the citations failed to mention any of the six ideas. The low percentage of citations not containing mention to the six ideas indicates that our interpretation of the article's main ideas closely aligned with the citing authors' interpretations.

With respect to the citing authors' prioritization of ideas compared to the hierarchy presented by Licklider, the results of this study indicate that each of the six ideas detailed in "Man-Computer Symbiosis" diffused across the 110 articles examined. However, in line with Licklider's emphasis, it is the idea for *symbiosis* that garnered the majority of citing authors' attention among the total number of ideas cited. Out of the total number of times (N=217) the six ideas were cited, *symbiosis* was cited 52.5% of the time. Put another way, of the 132 citations to Licklider contained in the set of articles examined, 86.3% of the citations contained a reference to *symbiosis*. Chi-square analyses revealed that authors publishing in the *humanities/social sciences* did not differ from those publishing in *science/technology* with respect to the ideas cited; hence, *symbiosis* was the most frequently cited idea regardless of discipline. Odds ratio analyses further reveal that when *symbiosis* was cited, it was often cited alone. These results support the claim that *symbiosis* was perceived by citing authors as the dominant innovative idea; that it did not automatically require the presence of the other ideas in order to be understood. This pattern of citation indicates that "Man-Computer Symbiosis" successfully diffused an agenda for attaining *symbiosis* among those citing it. The citation pattern also supports the observation that Licklider's ideas functioned on two levels: the primary abstract, conceptual level promoting *symbiosis*, and the secondary specific, concrete level promoting advances in five specific areas necessary to reach symbiosis. This hierarchy is further illustrated in Table 5.8 and Figure 5.2 in which citation to *symbiosis* consistently outperforms the other ideas in general and over time.

Interestingly, the odds ratio analyses (Table 5.11) reveal that the *language problem* was the one idea more likely (2.1 times) to be cited in conjunction with *symbiosis* than any of the other ideas. Although this study cannot definitively explain the reason behind this pattern, a plausible explanation is that the *language problem* variable—relating to communication differences between humans and computers, and the development of speech recognition software—was, as Licklider wrote, and continues to be, the most challenging area in computing compared with the other areas that he identified. In the Twentieth-century immense improvements have been made in the areas of multi-tasking, data storage and access, and interfaces between humans and computers. By comparison speech recognition programs lag behind these areas and, more noticeably, computers still fall short of being completely "user friendly."

Yet, it may be tempting to also conclude that Licklider's agenda was only partially adopted based on the observation that ideas related to the five areas for improvement were cited much less often than *symbiosis*. The follow up analysis for article subject areas (Figure 5.3) illustrates, however, that Licklider was cited in articles covering the specific areas—speed mismatch, memory hardware and organization, language problems, and input/output devices—outlined in his article. Additionally, revisiting Licklider's article, it is clear that the overarching innovation was his idea for *symbiosis*, which ran counter to the contemporary view of computers as room-sized, stand-alone calculators. The details for achieving symbiosis were comparatively more supportive of the innovation than innovations themselves. Odds ratio analyses (Table 5.11) support this observation revealing that when a subordinate idea (e.g., *memory hardware*) was cited, it was frequently cited in combination with another subordinate idea (e.g., *memory organization*). At the same time, Licklider's proposed solutions for these subordinate ideas contained innovative notions within them. Importantly, in detailing the *speed mismatch* problem, Licklider predicted the development of "thinking center[s]" to foster man-computer symbiosis which would take the form of "a network of such centers, connected to one another by wide-band communication lines and to individual users by leased-wire services" (p. 7). In essence, Licklider concisely laid out a vision and structure for the Internet in his discussion of the *speed mismatch* problem between humans and computers.

The preceding discussion partially explains that *symbiosis* received the majority of attention because it was perceived as the dominant innovative idea expressed in the article. However, other two additional factors not directly examined in this study may play a role in explaining the dominance of *symbiosis* and are worth discussing. The first factor is related to the meaning of the term symbiosis and the second to Licklider's application of the term.

Meaning and Application of Symbiosis

The idea for *symbiosis* may have been particularly effective at capturing the attention and imagination of others given its meaning and application. The term *symbiosis* is traditionally found in the biological sciences, where Licklider likely encountered this term during his studies in psychology. On the surface, the term symbiosis elicits the scenario of a mutually beneficial relationship between two or more organisms. Licklider described such a relationship in the article's opening sketch of the fig tree and the wasp. However, a standard definition of symbiosis in the *American Heritage Dictionary* states that it is "a relationship of two or more different organisms in a close association that may be but *is not necessarily* [emphasis added] of benefit to each other." Although Licklider set the stage for a mutually beneficial relationship in the fig tree and wasp scenario, he also hinted at the potential for a loss of mutuality when he speculated later in the article that computers may someday surpass human capabilities altogether. It appears then that his choice in using the term symbiosis was quite deliberate and the range of meaning contained in the term resonated with the citing authors.

Of additional interest regarding his word choice is how Licklider applied a biological term used to describe relationships between living entities to propose a cooperative relationship between an animate being, the human, and an inanimate object, the computer. Hence, in addition to redefining the human-computer relationship, he appropriated a biological term to define this new relationship and diffused it into the computer-related sciences. Recently, computer experts used a similar tactic to express concerns about the dominance of a single computer platform, Microsoft (Pope, 2004). In this article, the biological term *monoculture*, which states that species lacking genetic variation are most susceptible to cataclysmic epidemics, is applied to warn of the current dominance of a single computing platform, Microsoft. The lack of platform differentiation results in a heightened susceptibility of these unvaried networked computers to virus attacks. Thus we witness individuals in one branch of science borrowing terms from another branch of science in order to communicate better their visions of the future. Framing a non-biological vision in biological terms potentially makes for a unique and memorable example that may increase its salience in the minds of others.

Opinion Leaders and Change Agents

Licklider's role in promoting the idea for man-computer symbiosis ties into two types of individuals described by diffusion of innovations: the opinion leader and the change agent (Rogers, 2003). The opinion leader is defined as an individual within the targeted social system who is highly esteemed by members of the group and is thus empowered to promote an innovation's adoption from within the community. Opinion leaders are not necessarily innovative and tend to conform most to system norms, but upon adopting an innovation they are highly influential in persuading their peers to adopt. In instances where a setting favors change, opinion leaders may be innovators. When change is not favored, however, opinion leaders are not likely to be especially innovative or to be innovators. The change agent is defined as an individual or agency that exists outside of the social system in which the innovation is intended to diffuse. Change agents frequently identify and work through opinion leaders when attempting to diffuse an innovation into a system because they lack direct ties to the system members.

In addition to having access to a communication channel in the form of a scholarly publication in a science and technology journal, by 1960 Licklider was established in his career and enjoyed a certain level of esteem among his peers. This is evident from the fact that Jerry Elkind, editor of the fledgling *IRE Transactions on Human Factors and Electronics* and a former student of Licklider, invited Licklider to publish in the transactions. Even more notable is that Licklider's piece was the lead article in the first issue of the journal's first volume. These events support the observation that Licklider was viewed as an opinion leader among his peers in the research community. This conclusion is further supported by the spread of his ideas across a variety of authors at a number of institutions publishing in numerous sub-fields in the area of science/technology, and also to the application of his ideas to the introductory and theoretical/historical sections of these citing works.

However, Licklider was more than an opinion leader. He simultaneously played the role of change agent in that, at the time of his 1960 publication, his background in psychology made him a relative outsider compared to dedicated computer researchers in, for example, electrical engineering. This observation is supported in a statement made about "Man-Computer Symbiosis" by a former student of Licklider's, Robert Rosen, who studied computers:

> For the life of me, I could not imagine how a psychologist who, in 1956, had no apparent knowledge of computers, could have written such a profound and insightful paper about "my field" in 1960. Lick's paper made a deep impression on me and refined my own realization that a new age of computing was upon us (cf. Hafner & Lyon, 1996, p. 35).

Yet Licklider's previous defense experience with and continued interest in computers prompted him to promote their use at BBN where he was employed at the time that "Man-Computer Symbiosis" was published. Agenda-setting explains that by 1960 Licklider's former positions in the academy, the government, and the private sector provided him with the ethos and the technical expertise necessary to gain the attention of the research community for the purpose of promoting a research agenda based on his vision of man-computer symbiosis. Thus, Licklider had the vision for networked computing coupled with the credibility to promote this vision to the larger research community, and he had access to communication channels both informal and formal. He was not, however, interested in building the network himself; rather, by publishing his ideas and later holding additional positions of power in government agencies (e.g., IPTO) he was able to network with and assemble a group of individuals—his "Intergalactic Network"—who possessed the interest and knowledge necessary to realize his vision. These efforts eventually culminated in the construction of ARPAnet, the Internet's precursor. It is speculated by this study that Licklider's ability to function as both an opinion leader and a change agent acted as a catalyst for moving his vision of interactive computing from concept to reality.

Lastly, Licklider's role of an opinion leader and change agent is further supported by the use of his ideas in the citing articles examined. Regardless of the publication outlet, *humanities/social sciences* or *science/technology*, citing authors predominantly incorporated his ideas into the introductory and theoretical/historical context sections of their articles. Locating an author's work in these sections suggests that the ideas in "Man-Computer Symbiosis" were considered to be foundational for subsequent research in the area of human-computer relationships. Additionally, although it was not a variable in the code book, conversations with the Phase II coding team indicated that the coders perceived the citations to "Man-Computer Symbiosis" to be overwhelmingly favorable in tone with respect to Licklider's vision. Some examples from the articles analyzed include:

- The construction of an automatic speech recognizer would represent an important step in achieving an efficient, natural communication link between men and machines (Marill, 1961, p.34).
- Machines may also assist in problem finding. Real pioneers such as Licklider … have discussed some of the extraordinary benefits (and difficulties) of making digital computers more approachable in the sense of establishing two-way interplay between man and machine (Mackworth, 1965, p. 52).
- In a seminal paper on man-computer symbiosis, Licklider described the expected development of a cooperative interaction between men and computers (Testa, 1974, p. 14).
- The age of interactive man-computer problem-solving systems commenced in 1960 with J. C. R. Licklider's paper on "Man-Computer Symbiosis" (Godin, 1978, p. 331).
- In essence, we are proposing that efforts need to be taken to bring about "man-computer symbiosis" in the adaptive testing area and that these efforts will have

great importance to the success of this new testing approach (Johnson & Johnson, 1981, p. 421).

- The second technology follows the suggestions of Licklider (1960) and Seibel (1972), providing a common surface which both the operator and 'computer' can write on and read from (Beringer, 1985, p. 276).
- The goal of such a system [DIRE: Distributed Information Retrieval Environment] is the man-computer symbiosis envisioned by Licklider to achieve an unprecedented degree of scientific productivity (French, 1994, p. 532).
- Licklider, in his classic paper on man-computer symbiosis, observed that people engaged in intellectually demanding work can spend a surprisingly large fraction of their time "getting into a position" to think (Nickerson, 1999, p. 309).
- For the past 40 years, most of the IT research community has focused on interactive computing, J. C. R. Licklider's powerful and human-centered vision of human-computer symbiosis (Tennenhouse, 2000, p. 43).
- The PC is everywhere and it is portable, but interaction is not as natural as Licklider (1960) would have hoped. Central to the arguments put forth by both Weiser and Licklider is the concept of thinking-computing dualism. Both seek to break down the boundaries that exist between people and technology, either by imbedding the technology or making the interaction more natural. Both strategies hold the key to ubiquitous computing (Stanton, 2001, p. 111).

The preceding quotes reflect the generally favorable tone that exists among the citing articles, indicating support for Licklider's vision and the research agenda he set forth in "Man-Computer Symbiosis." Additionally, these quotes illustrate how some authors used the article to set a broad foundation for their research while others showed how their research aligned with Lickilder's general and specific ideas.

Did "Man-Computer Symbiosis" Set a Research Agenda?

Jerry Elkind, former student of Licklider and editor of the *IRE Transactions* in 1960, opined that, upon publication, "Man-Computer Symbiosis" influenced others and helped Licklider to set a research agenda for computing in the United States (Waldrop, 2001). Elkind was not alone in this opinion, as demonstrated in Internet histories, oral histories, and other sources (Godin, 1978; Hafner & Lyon, 1996; Segaller, 1999; Taylor, 1989). What, then, do the results of this study suggest about this perception that persists over time?

When examining media and public agendas, for example, agenda-setting implies a causal relationship between the media and the public; more specifically, that media agendas affect or set public agendas (Kosicki, 1993). In the case of this study, the implied relationship is that the research agenda published in "Man-Computer Symbiosis" influenced the research agenda of researchers exposed to the article. Similar to the founding McCombs and Shaw (1972) study, which used a filter question to select a subject pool of interest, this study used citation analysis to identify, or filter out, a set of researchers who cited "Man-Computer Symbiosis," an indicator of exposure.

In order to establish a cause-effect relationship, three basic conditions must be met in the following areas: 1) temporal order, 2) association, and 3) elimination of alternative explanations (Neuman, 2000). For the temporal order requirement to be fulfilled, it must be established that the cause precedes the effect. Temporal order is necessary but by itself it is insufficient to establish causality. In this study, the temporal order requirement is fulfilled. The publication of "Man-Computer Symbiosis" precedes the publication of the citing articles.

The second condition of association is based on clarifying that the variables in question seem to work together or to occur in a patterned manner. As with temporal order, association is a necessary but insufficient condition for causality. Careful readings by the research team established that Licklider presented his research agenda in "Man-Computer Symbiosis" via a two-tiered hierarchy. *Symbiosis* was the dominant agenda idea, followed by a set of ideas outlining required improvements in computing (e.g., time-sharing, hardware, software). The results of a quantitative content analysis of citations to "Man-Computer Symbiosis" reveal that the pattern of reference to ideas in the citing articles was similar to the hierarchy presented by Licklider. Specifically, in viewing the total number of citations (N=132) to "Man-Computer Symbiosis," the majority (86.3%) of citations contained a reference to *symbiosis*; whereas, only 31.2% of the citations contained a reference to *speed mismatch*, the next most frequently occurring idea. Table 6.1 visually depicts the comparison between Licklider's hierarchy and the citing authors' hierarchy with respect to the six ideas. It is important to reiterate that Licklider's

Table 6.1

Comparison of Licklider's Hierarchy to Citing Authors' Hierarchy of Ideas

Licklider's Hierarchy of Ideas	Citing Authors Hierarchy of Ideas	% of Citations (N=132)
Symbiosis	*Symbiosis*	86.3
Speed mismatch	*Speed mismatch*	31.2
Memory hardware	*Input/output equipment*	15.1
Memory organization	*The language problem*	13.6
The language problem	*Memory Organization*	9.8
Input/output equipment	*Memory Hardware*	8.3

hierarchy was expressed in two levels: 1) the general idea for *symbiosis* and 2) ideas for the five areas needing advancement. Among the five areas requiring improvement (i.e., *speed mismatch*, etc.), Licklider did not necessarily indicate that his presentation order was the order in which researchers' should focus their attention. The order in which these five areas were addressed in subsequent research was left up to the individual researcher based on his or her area of emphasis. Comparing Licklider's two-tier hierarchy to the citing authors' hierarchy, we see the citing authors' hierarchy reflecting Licklider's. Both focus the majority of their attention on *symbiosis*, with the remaining ideas receiving less attention. Although Licklider did not specify an order among the five subordinate ideas, we see that both hierarchies list *speed mismatch* next. The remaining four ideas are reversed in order by the citing authors. This reversal is likely a reflection of the citing authors' particular areas of research. With respect to the condition of association, Table 6.1 indicates that the two-tiered agenda presented by Licklider was reflected in the citing authors' hierarchy, suggesting that the authors were influenced by the content of Licklider's article.

The third factor concerns eliminating alternative explanations for the cause-effect relationship. Experiments excel in this area because they allow researchers to control the conditions under which the variables of interest are examined. Such is not the case with this study. Given its goal to trace the spread and influence of ideas over time in the published archive, the experimental method was not appropriate for this type of data collection. Many agenda-setting studies lack an experimental component, which weakens the ability to establish a cause-effect relationship (Kosicki, 1993); however, studies using experiments have shown support for a cause-effect relationship between exposure to media agendas and their influence on public opinion (Dearing & Rogers, 1996). Still, it must be conceded that given the methods used in this study, even though “Man-Computer Symbiosis” preceded the citing articles, it is possible that an author citing “Man-Computer Symbiosis” was already thinking about this type of human-computer relationship prior to the article’s publication. When the article appeared, the author may have cited Licklider not because the ideas set a new research agenda for the author, but because these ideas aligned with the author’s pre-existing thoughts about new directions in computer research. Thus, Licklider’s agenda may have reflected other researchers’ thinking rather than reshaping their thinking. In future research on this topic, a macro-level analysis may offset this limitation. A pre-1960 and post-1960 keyword search on the term *symbiosis* conducted in the engineering literature may add clarity to the influence of “Man-Computer Symbiosis.” Given Licklider’s unique use of the term, if noticeable increased use of the term *symbiosis* (a term primarily used in the biological sciences) occurred in research publications after the 1960 debut of “Man-Computer Symbiosis,” then this would lend additional support to the article’s influence among researchers. Within the confines of this project, of the three conditions necessary to establish a causal relationship, this condition is not clearly met.

Did “Man-Computer Symbiosis” set a research agenda? Of the articles examined in this study, the temporal order and association conditions for establishing a causal relationship between Licklider’s article and subsequent citing articles imply that “Man-Computer Symbiosis” influenced citing authors. However, it cannot be stated with absolute confidence that alternative explanations for this apparent influence do not exist. Thus, with respect to this question, the setting of a research agenda by Licklider, though strongly suggested by the results, remains more a matter of perception than an irrefutable reality.

The Importance of “Man-Computer Symbiosis”

Given the emphasis placed by Internet histories and other sources on the defining role of Licklider and “Man-Computer Symbiosis” in fostering a shift to research and development in interactive and networked computing, a question that remains to be addressed is the importance of the article in light of this study’s findings. If one goes strictly by raw citation counts, then the 110 articles that comprise this study call into question the influence of the article given this rather low number when one considers the ISI highly cited authors series in which some authors’ collected works are cited 50,000 times or more (ISI, 2001a). However, to dismiss the article as unimportant based solely on the citation count is premature. Reliance on raw citation counts as an indicator of importance can be misleading because in reality citation counts vary widely across disciplines, as do citation practices among authors (Cronin, 1984). Due to these variations is difficult to state with a high degree of confidence the average number of times a typical article is cited. Additionally, as illustrated with the ISI example above, citation counts are often based on a collection of authors' works rather than on a single piece. When assessing the importance of "Man-Computer Symbiosis," then, other factors to consider include: consistency in citation over time, pattern of diffusion, the types of journals in which citing articles are published, the institutional affiliations of the citing authors, and the citing authors themselves.

With respect to consistency of citations over time, Figure 5.1 and Table 5.6 illustrate the steadiness with which "Man-Computer Symbiosis" has been cited over a 40-year timeframe. This stable pattern is particularly notable because it indicates that a "dilution effect" has not occurred with this article. As previously stated, the dilution effect refers to the reduced chances for a published work to be cited over time given that in addition to competing with existing works, it must also compete with newly published works in an ever increasing pool of publications. With "Man-Computer Symbiosis" we do not see clear evidence of an exponential rate of decline in citations. The moving averages trendline in Figure 5.1 indicates that the average number of citations to the article per year has remained stable between 1961 and 2001. Thus, entering its fifth decade from publication, the article is still being cited. Interestingly, projections for the 2000s suggest that we may see an increase in citations to the article within the *humanities/social sciences* and in the overall count.

The diffusion or adoption curve for "Man-Computer Symbiosis" is illustrated in Figure 6.2. Although the article's diffusion curve differs from the traditional S-curve, the figure clearly depicts a steady and continued diffusion of the article within the research community. Figure 6.1 further defines the article's diffusion pattern. It indicates that initial adoption of Licklider's ideas resided primarily among authors publishing in *science/technology* outlets, followed by a noticeable spread of the ideas among authors publishing in *humanities/social sciences* outlets beginning in the 1990s and appearing to continue into the 2000s. These patterns indicate that researchers across disciplines continue to find sufficient relevance in the content of "Man-Computer Symbiosis" to cite it in their own works.

As noted in Table 5.7, five journals contained more than half (56.5%) of the 110 citing articles. The journals, in descending order, include: *International Journal of Human-computer*

Studies, *Human Factors*, *Proceedings of the IEEE*, *Communications of the ACM*, and *IEEE Transactions on Systems, Man, and Cybernetics*. As indicated by the *ISI Journal Citation Reports*, these journals are respected and reputable engineering publications covering research in the areas such as electrical engineering, computing, and ergonomics (available via subscription from http://www.isinet.com). Citation by articles published in these journals places the cited article in with an elite group and potentially exposes the cited article to a large group of researchers given the journals' reputations. More importantly, citation by articles published in these journals speaks about the citing researchers themselves, indicating that these are individuals conducting quality research in their respective areas. The concentration of citing articles of "Man-Computer Symbiosis" in top-tier science and technology research journals strongly suggests that the article is perceived as making an important contribution to the research community.

The institutional affiliation of the citing authors is another indicator of importance. Roughly one-third (34.1%) of the 88 organizations represented by citing authors were concentrated at the following locations, listed in descending order: University of Illinois, Bolt, Beranek & Newman (BBN), Bell Labs, Texas Tech University, and University of Maryland. Notably, two of these five organizations are in the private sector indicating the article's spread beyond the walls of the academy. Both BBN and Bells Laboratories are reputable organizations. Notably, BBN was awarded the ARPAnet contract in 1968. Additionally, Licklider was employed there between 1957 and 1962 (Segaller, 1999). It is possible that citation to Licklider by BBN authors was a homage paid to a previous employee, but it seems more likely that, given his previous affiliation with BBN, Licklider's work was well known and relevant to these authors. And, although AT&T was slow to embrace computer networking in the 1960s, their research and development group, Bell Laboratories, has been and continues to be well respected for its technological innovations (Hafner & Lyon, 1996). Among the universities listed, the Center for Advanced Computation at the University of Illinois was the twelfth network node on ARPAnet in the 1970s. Additionally, in 1993 Marc Andreessen and other students at the university's National Center for Computing Applications created an early web browser called Mosaic, which helped to popularize the World Wide Web and the Internet. Mosaic later evolved to become Netscape Navigator. The University of Maryland participated in creating SURANet during the early 1980s, which separated itself from ARPAnet to connect universities and commercial entities for information exchange. The University of Maryland was also the last node to be disconnected from APRAnet when it was dismantled in 1989 to be replaced by the NSFNET and other regional networks. In addition to these organizations, a number of other well-known institutions have published articles citing "Man-Computer Symbiosis" such as: MIT, Purdue, Stanford, General Electric, Intel, Microsoft, Rand, U. S. Department of Defense, and the National Science Foundation. Clearly, these institutions represent an elite mix of academic, private sector, and government groups by which to be cited.

Lastly, we consider the citing authors for "Man-Computer Symbiosis." The study results reveal that the majority (79.9%) of authors who cited "Man-Computer Symbiosis" were unique (non-repeating) authors, illustrating the article's wide reaching nature among the citing authors examined. Three authors cited Licklider three or more times: Brian R. Gaines, Larry Press, and William B. Rouse. Gaines cited "Man-Computer Symbiosis" four times over a ten-year period between 1976 and 1986. His articles focused on interactive and new generations of computing. Gaines was affiliated during this time with the University of Essex, the Centre for Man-Computer Studies in London, York University, University of Toronto, and the University of Calgary. He chaired the Electrical Engineering Science Department at Essex and was editor of the *International Journal of Man-Machine Studies*. He was also a member of departments of computer science and industrial engineering. Larry Press cited "Man-Computer Symbiosis" four times between 1986 and 1996. Press's articles focused primarily on the history of computing. At the time of his publications, Press was a professor of computer information systems in the California State University system. Lastly, William B. Rouse cited "Man-Computer Symbiosis" three times between 1975 and 1981. Rouse's articles focused on human-computer interfaces and interactions in dynamic environments. Rouse was affiliated with the Department of Mechanical and Industrial Engineering and the Coordinated Science Laboratory at the University of Illinois where his research was supported by grants from the U. S. Air Force and NASA. In this brief snapshot of the three authors who cited Licklider most frequently, we see that Gaines, Press, and Rouse held academic positions in technical fields at upper-level respected institutions.

In reaching a conclusion about the importance of "Man-Computer Symbiosis" based on the study results, a number of factors are examined: total citation count, consistency in citation over time, pattern of diffusion, the types of journals in which citing articles are published, the institutional affiliations of the citing authors, and the citing authors themselves. The overall citation count for “Man-Computer Symbiosis” appears low when considering that some authors’ collected works are cited 50,000+ times; however, as noted earlier, counts vary by discipline as do citation practices, making this number only one of several factors to consider in determining importance. Additionally, we are examining a single article instead of a collection of works. The other factors reveal the following four observations about the influence of “Man-Computer Symbiosis”: 1) over time, “Man-Computer Symbiosis” has received a consistent level of citation despite the fact that it competes with an ever-increasing pool of research articles; 2) the article’s rate of adoption has been steady during the examined 40-year timeframe and the adoption curve indicates that it is still diffusing into the research community, with increased adoption occurring in the *humanities/social sciences*; 3) the journals in which the majority of citing articles are published are highly respected in their fields; 4) the citing authors are affiliated with highly respected academic, private sector, and government organizations, many of which have made important contributions to the Internet’s development, and 5) brief profiles of the three authors who most frequently cited “Man-Computer Symbiosis” reveal that they held academic positions in technical fields at upper-level respected universities. Based on this analysis, it is concluded that “Man-Computer Symbiosis” is in fact an important article. The citation count may be low, but the article’s reach over time as well as among the researchers, institutions, and journals examined is concentrated in the top-tiers.

The Role of a Scholarly Article in Diffusing Ideas

This study depicts the role of a scholarly article in diffusing a set of ideas among members of a research community over a 40-year period. Although citation analysis cannot explain why one author decides to cite another, it successfully identified the influence network produced by citing articles. Given the narrow coverage of the citation indexes used by this study, the results are a conservative estimate at best of the influence network generated by the publication of “Man-Computer Symbiosis.” The identified network was subsequently analyzed using quantitative content analysis to examine the spread and influence of ideas contained in a source article among citing articles.

In “Man-Computer Symbiosis” the overarching idea for symbiosis diffused widely among the 110 articles examined. Jerry Elkind, the journal editor to whom “Man-Computer Symbiosis” was submitted, commented that Licklider’s article “…essentially laid out the vision and the agenda that would animate U.S. computer research for most of the next quarter century, and arguably down to the present day" (Waldrop, 2001, p. 176). Although Elkind did not explicitly reveal the research agenda in his statement, the results from this analysis indicate that citing authors were most influenced by Licklider's overarching idea (or vision) for *symbiosis*.

The results from this study add support to the notion that despite its procedural idiosyncrasies scholarly publication promotes the sharing of ideas and indicates that some articles are capable of diffusing ideas over extended spans of time. The results also support historical perceptions about an article's role in setting a research agenda. As noted in the previous section, while the overall citation count to "Man-Computer Symbiosis" may be considered low, it has predominantly diffused among an elite group of researchers residing at respected and influential institutions, the majority of whom have cited Licklider's idea for *symbiosis* in research that is published in top-tier research journals.

Theoretical Contributions

This study makes a theoretical contribution by demonstrating the usefulness of combining diffusion of innovations and agenda-setting to trace and explain the spread and influence of ideas among a set of researchers over time. Application of these theoretical perspectives to tracing an idea expands the use of these theories within the communication discipline, which, for example, has primarily focused on examining the diffusion of technological devices and investigating agenda-setting in the news media. Expanding the application of these theories speaks to general criteria used to evaluate the overall effectiveness of social scientific theory: practical utility and generality. Practical utility refers to applying theory to improve understanding of daily practices. In this study, diffusion of innovations and agenda-setting successfully guided an analysis investigating the spread and influence of ideas communicated in academic publications over an extended timeframe. Publication is a routine practice in the research community, serving as a formal line of communication. Generality refers to a theory's ability to explain a wide array of phenomena. As noted by Rogers (2003), diffusion of innovations is widely applied across disciplines and topics in general. Within communication, however, application of diffusion is somewhat narrower in focus. This study builds upon Aikat's (2001) study of computing pioneers and expands the use of diffusion within the discipline to trace the spread of a set of early ideas for interactive computing. It also expands the use of agenda-setting by applying it to investigate the role of a particular communication channel in setting a research agenda within a smaller social system, the role of publication in the research community. The majority of communication studies examine the news media's role in influencing the general public and policy agendas. This study indicates that agenda-setting occurs on multiple levels within society. Future studies may wish to explore the role of agenda-setting in other organizational and smaller community settings.

Additionally, this study suggests that an individual may simultaneously function as an opinion leader and a change agent by operating within a specific sub-system (e.g., psychology) that is part of a larger social system (e.g., researchers). For Licklider, interacting with computers was initially an aside from his main focus, psychology. When Licklider accepted employment with BBN in the early 1960s, he was instrumental in persuading the organization to adopt computers based on interactions he had while previously employed at MIT. In this sense, Licklider functioned as a change agent among computing researchers by functioning as an outsider both in terms of previous employment location and field of study. However, within the larger research community, Licklider functioned as an opinion leader by publishing his ideas and later accepting positions that enabled him to make his visions for man-computer symbiosis viable among a scientific community of researchers. Diffusion presents the roles of change agents and opinion leaders as typically occupied by different individuals. Licklider is an exception to the rule. This dual role held by a single person may function as a catalyst for diffusing ideas more widely in a shorter span of time and it may make the individual more memorable with the passage of time than when separate individuals hold these positions; however, it is not within the scope of this study to make a definite claim in this area, which suggests an area for future research.

With respect to the agenda-setting process, this study illustrates the useful application of the perspective in a manner that differs from its mainstream application to news media. Specifically, this study draws parallels between a macro-level approach that focuses on news media, public opinion, and public policy outcomes and a micro-level approach that focuses on scholarly publication, the research community, research outcomes to demonstrate the role played by agenda-setting in smaller-scale environments. In this particular case, agenda-setting provided insight into the influence of ideas over time by addressing questions related to who set the research agenda, how the research agenda was set, and the extent to which the agenda was reflected in other researchers' works.

In conclusion, diffusion of innovations and agenda-setting are more scalable than they may appear to be at first glance. By applying them in contexts different from the majority of communication studies, we begin to see where the theories hold up and where they are less relevant. In this study, diffusion of innovations excelled at explaining the characteristics of the diffusion networks into which Licklider's ideas spread (homophilous versus heterophilous networks), the role that time plays in the adoption process (exponential versus sigmoidal rates of adoption), and the role of opinion leaders and change agents in promoting innovations (roles held by separate individuals versus both roles held by a single person). Given the focus of the study, adopter categories and innovation characteristics were less relevant to the questions asked for two reasons. First, researchers by definition tend to be innovators or early adopters given their mission to be on the "cutting-edge." The delay in "Man-Computer Symbiosis" spreading into the *humanities/social sciences* is less likely due to those researchers being laggards and more likely due to the fact that they occupy a communication network that is heterophilous in nature when compared to the *science/technology* group. Heterophilous networks tend to function as communication barriers for the spread of innovations, at least initially.

Second, the innovation characteristics—relative advantage, compatibility, complexity, observability, and trialability—can be more difficult to apply to an abstract idea than to a physical product. Of the five characteristics, relative advantage, compatibility, and complexity are easiest to apply to Licklider's overarching idea for *symbiosis*. *Symbiosis* offered an improved and potentially more beneficial vision for the future role of computers that communicated a "big picture" for integrating specific aspects of computing (e.g., time sharing, hardware) in a manner that was easy for others to comprehend, at least conceptually. However, because it was initially an idea ahead of its time and the actual technological means by which to accomplish *symbiosis* were still in the making, *symbiosis* was not something that could easily be witnessed or experimented with directly by others. With the passage of time and subsequent technological breakthroughs in computing, the observability and triability characteristics of *symbiosis* are more easily experienced now, though perfect *symbiosis* is still an ideal rather than a reality.

With agenda-setting, the theory excelled at explaining the "who, what, how, and influence" of the process by which Licklider formally communicated his ideas to other researchers. The study results inform us that Elkind and Licklider set a research agenda via a research publication emphasizing a new focus on *symbiosis* and the means to attain it. Licklider's agenda appeared to be reflected in citing authors' research, though the study design does not permit a definitive conclusion on this point. The theory also fits well within the initiation phase of diffusion within organizations (Rogers, 2003) to provide a link between the two processes and to demonstrate the relevance of agenda-setting to smaller-scale environments. The policy area of agenda-setting was not emphasized in this study, although historical accounts suggest that Licklider's article was at least indirectly responsible for promoting the development of ARPAnet, a research outcome (Hafner & Lyon, 1996; Segaller, 1999; Taylor, 1989).

Methodological Contributions

The successful application of citation analysis and quantitative content analysis in this study demonstrates the usefulness of combining these data collection techniques to trace the spread and influence of ideas over time. In particular, as indicated by the intercoder reliability results (Table 5.1), this study demonstrates that quantitative content analysis can be used effectively to create measures for identifying the presence of abstract ideas. More specifically, counter to the general opinion of some content analysts (e.g., Holsti, 1969; Riffe et al., 1998), quantitative content analysis can successfully identify content possessing latent characteristics, rather than being limited strictly to manifest content.

In this study, a combination of manifest and latent content was coded. Manifest content existed in the coding of article variables (e.g., author name, affiliation, year of publication) that were directly observable and easily identified. That is, a coder encountering the author, John Smith, simply records or verifies the author name on the coding sheet. There is no requirement for the coder to exercise judgment about the degree to which John Smith is an author. Intercoder reliability is high with this type of coding because identifying the author is straightforward. The typical errors that might occur with this type of coding are fatigue and haste so that the coder misreads the author name and codes Jack Smith instead of John Smith or misses the author altogether.

With the idea variables (e.g., *symbiosis*, *speed mismatch*), the coding scheme necessarily contained a combination of manifest and latent content. If we had been strictly manifest content oriented in this study, then coders would have coded for the presence of the *symbiosis* idea if and only if the term *symbiosis* appeared in the citation; the presence of *speed mismatch* if and only if the phrase *speed mismatch* appeared in the citation. To code so literally, however, would result in a very narrow study that greatly underestimated the presence of the six ideas by not being sensitive, for example, to synonyms for Licklider's terms. Thus, in addition to containing Licklider's terms, the idea variable coding scheme specified certain words and phrases for coders to look for in the citations to indicate an idea's presence. The coding scheme was manifest-like in that the terms and phrases were largely derived from the wording and structure used by Licklider in "Man-Computer Symbiosis" and their actual presence in the citations signaled a coder to code for the related idea's presence. Thus the coding scheme attempted to account for changes in terminology over time; some ideas included synonyms not included in Licklider's article. For example, *speed mismatch* and *time-sharing* are synonymous with the current term *multi-tasking*. A listing of words and phrases for each idea was necessary to guide coders and to improve intercoder reliability.

The coding scheme also contained elements of latent content in that it could not possibly contain an exhaustive listing of all possible terms signaling an idea's presence, nor could it completely remove the overlap shared by some of Licklider's ideas. For example, *memory hardware*, which focuses primarily on the physical components of data storage (e.g., drums, tapes, disks), is closely linked with *memory organization*, which focuses primarily on the software for navigating and accessing the data contained on the hardware (e.g., operating systems, file structures). Computer hardware requires software to function and visa versa. Thus a citing author making general reference to Licklider's call for improvements to the creation of file directories may be tapping into the *memory hardware* idea (e.g., the ability of the computer to physically create space on the drive by depositing magnetic charges on the disk) or the *memory organization* idea (e.g., the programming instructions that tell the hardware how to create space on the drive) or both. Coders encountering this scenario had to read on either side of the citation to ascertain the citing author's meaning by gaining additional context while also recalling how they handled preceding situations of a similar nature. This experience is akin to the scenario of trying to concisely define the term "chair." If one defines "chair" as a structure possessing four legs, a seat, and a back then how does one account for a pedestal structure supporting a seat with a back and armrests? Yet, by examining a piece of furniture most of us can agree on what qualifies as a "chair" even though we lack a concise definition. Thus, the coders learned to recognize the presence of an idea when they saw indicators of it despite lacking a complete definition. Over time, the coders, through practice and discussion, developed a schema for determining how to handle ambiguous content that could not be explicitly spelled out in the code book.

Specifically, the coders dealt with content closely related to a specific form of latent content referred to as *pattern content*. To restate, "With *pattern content*, the designer of the content analysis puts precedence with the content and believes that there is an objective pattern there that all coders should uncover by sorting through symbols and recognizing the connections among them [emphasis in original] (Potter & Levine-Donnerstein, 1999, p. 259). While the specific words and phrases in the coding scheme guided coders in determining the presence or absence of Licklider's ideas, as noted above, at some point the coders had to make judgments about a citing author's intent. In these cases, precedence was placed on the content itself and coders, reading further for additional context and recalling to previous situations, made coding judgments based on patterns they observed within and across the content in citing articles. Returning to the preceding *memory hardware/memory organization* example, coders encountering a citing author's reference to Licklider's call for improvements to file directories would not automatically code these two ideas absent simply because the phrase "file directories" was not listed in the coding scheme. Rather, intuiting that reference to an idea or ideas was present in the author's citation, the coders would combine their understanding of the coding categories with their understanding of the author's meaning to reach a coding decision. The intercoder reliability results demonstrate that this process was successful and that quantitative content analysis need not be strictly limited to examining manifest content.

In concluding this section on content analysis, it is important to note that, where possible, when coding for the presence of Licklider's ideas attempts were made in the code book to provide concrete or manifest examples that would trigger a coding response for the purpose of improving intercoder reliability. Does this mean then that the ideas coded in the study were not latent in nature? The answer is no. To further illustrate this point consider the following: Had we also coded for authors' tone, a latent variable, in the citations to "Man-Computer Symbiosis" (which is recommended in future studies), we still would have operationalized the variable (e.g., favorable, unfavorable, indeterminate) and then attempted to include some example phrases or keywords (e.g., "highly influential," "questionable") to guide coders' decisions. At a minimum, coding of the ideas in this study occupied a middle ground between manifest and latent content, and the research team successfully navigated the terrain.

With respect to citation analysis, the method successfully identified the influence network for "Man-Computer Symbiosis" that exists in the ISI Citation Indexes. Citation analysis acts as a data-mining tool to sift through millions of articles to locate only those articles of interest as specified in the cited reference search request. Where the method falls short is in a combination of citation practice variations and limitations in the current citation indexes. As noted in the Methods chapter, cited reference searching can be a complicated process given that authors make citation errors and that the citation styles differ sufficiently enough to produce scrambled results that the researcher must wade through to determine the final article set. The other glaring limitation is related to the narrow coverage of the citation indexes. Although ISI claims to index the leading journals across disciplines, anyone attempting to gain a comprehensive view of an article's influence will receive a partial view at best. Development of new and improvements to existing electronic search tools will, in time, expand researcher access to published archives thereby offsetting this limitation. In the meantime, should researchers seeking to understand a work's influence over time abandon the ISI indexes? The answer is absolutely not. Rather, they must be sensitive to the limitations of the indexes and the method by fully disclosing these challenges in their research.

To conclude, citation analysis worked best as a data-mining tool that sifted through millions of ISI indexed articles to identify an influence network generated by the publication of "Man-Computer Symbiosis." Interpreting an author's decision to cite a work as an indicator of influence, citation analysis also offset the reduced ability of quantitative content analysis to examine the effects of messages. Where citation analysis fell short in this study had less to do with the method itself and more to do with current limitations in the citation indexes. Specifically, the ISI indexes cover a very narrow segment of the total number and types of publications that exist. At best, we are presented with a conservative estimate of the article's spread and influence within a narrow range of research publications. Future incorporation of cited reference searching by other electronic resources (e.g., WorldCat, which indexes monographs) would offset the narrow coverage of the current citation indexes to provide researchers with access to a wider range of citing documents.

Quantitative content analysis worked best to identify which of Licklider's ideas were referenced in the works of others. More specifically, the frequencies and patterns of these references provided an overall picture of how Licklider's hierarchy was reflected in the works of a set of citing authors over time. Quantitative content analysis offset the inability of citation analysis to reveal the content of the citations. The method also verified the information provided by the cited reference search results (e.g., author name, journal title, year of publication) to reveal generally accurate reporting by the citation indexes, while also providing additional article information not provided by the cited reference search, such as author position and institutional affiliation. In retrospect, additional variables that might have been coded in the study include: the specific subject areas of the citing articles, the positions of the citations within the citing articles, and the general tone (e.g., favorable versus unfavorable) of the citations. Although these variables were not part of the quantitative content analysis, follow up qualitative analyses did provide insight about this content; however, conclusions based on these results could not be made with the same degree of confidence as with the variables that were included in the quantitative content analysis.

Chapter Summary

In this chapter, the study results are summarized on three levels: the substantive, the theoretical, and the methodological. Substantively, the results indicate that Licklider's article set forth an agenda encouraging readers to think about achieving *man-computer symbiosis* via technological improvements in five areas related to computer processing, data storage, data retrieval, programming/communication, and interface design. Of the citing articles examined, the influence network through which Licklider's ideas diffused is characterized as primarily homophilous during the first 30 years from the date of publication, with articles published predominantly by academicians in science and technology journals. The idea for *symbiosis* diffused the most widely of the six ideas examined and was consistently cited more often than the other ideas over time. The majority of citations to "Man-Computer Symbiosis" occurred in the introduction and theory/historical context sections of the citing articles, indicating widespread use of Licklider's work as a framework for others' research. These patterns of citation to Licklider's ideas were evenly distributed between authors publishing in the *humanities/social sciences* and those publishing in *science/technology* journals.

Theoretically, this study illustrates the strength of combining two perspectives, diffusion of innovations and the agenda-setting function, to more thoroughly understand the spread and influence of ideas in scholarly/professional publications. The study also demonstrates an application of these perspectives that differs from their usual application in the communication discipline. In turn, successful application of these perspectives to less examined areas within the discipline expands the generality and practical utility of both diffusion and agenda-setting.

Methodologically, combining citation analysis with quantitative content analysis maximizes their strengths and minimizes their individual weaknesses to produce a strongly defensible data set from which conclusions about the spread and influence of "Man-Computer Symbiosis" can be drawn. Citation analysis informs us about who was influenced by Licklider's article by identifying citing articles and their authors. Quantitative content analysis reveals patterns in citation to six ideas expressed by Licklider over a 40-year timeframe. The study results add a new, more detailed dimension to our understanding about Licklider's contributions and the influence of his publication. The study results coupled with interview reports and historical research about the Internet support the notion that "Man-Computer Symbiosis" was and continues to be an influential writing in its promotion of improved relations between humans and computers.

CHAPTER SEVEN

CONCLUSION

The analysis of “Man-Computer Symbiosis” successfully demonstrates the practicality of combining diffusion of innovations with the agenda-setting function while pairing citation analysis with quantitative content analysis to trace the spread and influence of a scholarly publication among a community of researchers over an extended timeframe. However, as with any study, certain limitations and strengths exist in concept, process, and interpretation. A research project also generates questions that cannot be answered readily by the data collected, suggesting additional areas for future research. This chapter addresses these areas, ending with an observation about the overall contribution of Licklider’s “Man-Computer Symbiosis” in light of the applied theories and methods.

Limitations and Strengths of the Study

This study is limited to examining only the authors and journals indexed by ISI. It cannot account for individuals influenced by Licklider who incorporated his ideas into their research but did not 1) formally cite him, 2) publish in an outlet indexed by ISI or 3) write about him at all. Additionally, the citation indexes focus primarily on academic/professional journals as well as select conference proceedings and monographs. The ISI indexes do not, for example, include any of the popular press Internet history texts or classroom texts cited earlier in this study (e.g., Barnes, 2003; Gray, 2001; Hafner & Lyon, 1996; Waldrop, 2001), which contain citations to “Man-Computer Symbiosis.” Nor do the ISI indexes contain trade publications such as *Wired* or *PC World* that may also contain citations to Licklider. Government research reports are also under-represented. This particular limitation may eventually be remedied or at least partially offset by current efforts to digitize texts. A recent article in *Wired* (Wolf, 2003) reports on initiatives by groups such as Amazon.com to digitally scan texts, partly for the purpose of rendering their content keyword searchable via the computer. While books, for example, are valued for their portability, a longstanding problem is the difficulty in locating specific information within their numerous pages, even with table of contents and indexes. Adding a keyword search function makes examining the content of books more feasible and greatly broadens the boundaries of the examiner's scope. Thus, the primary limitation of citation analysis in this study is not a function of limits in the method itself; it is a function of the current restrictive coverage of the citation indexes.

Despite the aforementioned limitations, this study possesses a number of strengths. Combining diffusion of innovations and agenda-setting provides a more robust explanation of the influence network than either perspective alone. For example, diffusion provides insight into the largely homophilous nature of the influence network and also explains the recent increased spread of Licklider's ideas into heterophilous networks (i.e., *humanities/social sciences*). Diffusion also depicts the role of time in the process to reveal an innovation's rate of adoption, in this case an exponential curve. Agenda-setting demonstrates Licklider's effectiveness at promoting the idea for man-computer symbiosis via his perceived credibility among peers and his access to a communication channel by which to disseminate his ideas. The data support the existence of agenda-setting by revealing the predominance of citations to symbiosis relative to his other five ideas, which appears to mirror the hierarchy of ideas that was established in "Man-Computer Symbiosis."

Similarly, combining citation analysis and quantitative content analysis maximizes their strengths and minimizes their weaknesses. Citation analysis excels at identifying influence networks but is weak at revealing the context of the citations themselves. Quantitative content analysis excels at examining the context of messages (e.g., citations) but is weak at providing insight into message influence. By pairing these data collection techniques, we can investigate influence in the form of citing articles and authors while more specifically analyzing the messages (e.g., ideas) contained in the citations themselves. Additionally, applying quantitative content analysis rather than qualitative content analysis provides a more defensible foundation for making general claims about citation content. The successful use of independent content coders and confidence intervals produces a data set increasing researcher confidence that others using the same selection and coding procedures would obtain similar results, more so than if the data were collected by a single individual.

Future Research

Several areas for future research are suggested by this study. For purposes of consistency and organization these areas are broken into substantive, theoretic, and methodological sections.

Substantive

Substantively, one area involves examining the citation networks of two subsequently published but related articles by Licklider, "Man-Computer Partnership" (1965) and "The Computer as a Communication Device" (1968). Comparing these citation networks with that of "Man-Computer Symbiosis" would enable us to address questions such as: What do the citation networks of all three articles tell us about their overall influence—are the same authors citing all three or are new authors joining in, and, if so, who, how many, and from where? Additionally, co-citation coupling and bibliographic coupling may be applied to examine the degree to which these three articles are related in terms of their cross-referencing of one another. The overall goal of this line of inquiry is to place a single article, "Man-Computer Symbiosis," within the context of a larger citation network involving two additional publications by the same author, to examine the similarities and differences in individual and combined networks. Lastly, examining the reference lists of the 110 citing articles for "Man-Computer Symbiosis" may reveal the existence of "bridges" (Rogers, 2003) or points of contact between authors publishing in *science/technology* and those publishing in *humanities/social sciences* journals. Such information would provide a clearer picture about the possible existence of researchers in the citation network who have functioned as links between the heterophilous networks, *humanities/social sciences* and *science/technology*.

Another line of research suggested by this study, that is similar to the Rogers and Dearing (1993) study of the intellectual history of agenda-setting, is to take a broader view of the paradigm shift proposed in "Man-Computer Symbiosis." Licklider promoted a shift from computers as stand-alone calculating devices to computers as interactive and networked tools. Rather than focusing on the directly observable influence network generated by citing works, this line of inquiry would examine the occurrence of the word *symbiosis* in engineering publications pre-1960 and post-1960 to examine any evidence suggesting an increased use of the term by researchers subsequent to the publication of "Man-Computer Symbiosis." The resulting publications would then be examined to ascertain direct (e.g., article contains a citation to "Man-

Computer Symbiosis") and indirect (e.g., article cites an article that cites Licklider) links to Licklider's article as an alternative measure of influence.

Theoretical

From a theoretical perspective, one line of research suggested by this study involves identifying general characteristics of influential articles by comparing patterns of citations across highly regarded publications such as Vannevar Bush's "As We May Think" and Alan Turing's "On Computable Numbers, with an Application to the Entscheidungsproblem." The end goal in this case is to develop a general set of characteristics that highly respected and influential works typically embody (e.g., overall citation count; consistent citing over time; consistent reference in citing articles to an innovative idea or theme; centrality of authors, institutions, and journals). In time, this information may be general enough in nature to apply across disciplines, functioning as a basic tool for identifying and assessing influential research in a field that goes beyond raw citations counts alone. Diffusion of innovations and agenda-setting would be applied to these investigations in a manner similar to this study to enable comparisons between the results for the abovementioned publications. A related line of research involves analyzing additional instances where an individual fills both roles of opinion leader and change agent. For example, did Bush, Turing, von Neumann, and Wiener function in both roles, similar to Licklider? If so, then this may be a factor in determining what makes a publication influential or at least perceived to be so.

Lastly, the results of this study show promise for future research combining diffusion of innovations with agenda-setting to trace the spread and influence of ideas over time. In particular, agenda-setting does not have to be limited to the mass media, particularly the news media, and the general public or national level policy-making. As Dearing and Rogers (1996) note, all social systems (large or small) contain agendas that help them to prioritize the handling of issues. The flexibility in defining the social system is key. A social system can be a nation, a business, a research community or a neighborhood. In each setting, agendas are set and acted out. Within organizations and other innovative environments (e.g., research community), agenda-setting in the initiation phase of an innovation closely parallels agenda-setting in the mass media, public, and policy arenas. The traditional agenda-setting questions related to who sets agendas, who is affected by the agendas, and what are the policy and procedural outcomes of these agendas are as relevant in smaller scale organizational and community settings as they are in traditional contexts examined by agenda-setting research, particularly when an individual or group is attempting to modify the status quo.

Methodological

Methodologically speaking, current initiatives to index web pages and the contents of books will provide future research opportunities not limited to the ISI indexes. Once these Internet accessible search services become available, a follow up study to this project may be conducted to present a clearer picture of the influence network for “Man-Computer Symbiosis” as documents previously excluded from cited reference searching are made available. Given that Licklider worked for and ARPAnet was part of the U. S. government, a search for citations to “Man-Computer Symbiosis” in government document databases may yield yet another influence network. Examining this network would foster comparisons and contrasts between the results of this study and the results of the government research reports to produce a broader perspective on the article’s spread and influence. The biggest challenges to this proposal are the difficulties associated with successfully navigating the government document databases and locating the documents given the somewhat cumbersome system used to classify these reports.

A general search of the World Wide Web using a search engine may reveal a third influence network comprised of web pages, web sites, and other published documents citing “Man-Computer Symbiosis.” An advantage to this type of search is that it potentially enables us to see the article’s influence among the general public given that a broader segment of individuals can publish online in comparison to more restrictive outlets (e.g., journals, books). A web search would also provide access to news sites and their archives, although currently the search features of these sites do not tend to be sophisticated enough to handle cited reference inquiries; searching newspaper databases may offset this particular limitation. A challenge of conducting a web search lies in accurately classifying the citing sources (e.g., personal site, business site, government site) in order to present a broader picture of the article’s influence. Another challenge is reflected in the relative impermanence of web publications, which appear and disappear daily, compared to the more permanent print and database archives.

The greatest challenge to these proposed search alternatives is that they lack the cited reference search capability offered by the ISI citation indexes. This limitation makes locating additional citing sources a more time-consuming and potentially less fruitful endeavor. Ultimately, access to a larger population of documents—government reports, newspaper columns, web publications, popular press and academic monographs— particularly if they include a cited reference search feature, will help to offset the limitations of citation analysis that pertain to under-represented publication outlets in the currently available citation indexes.

With respect to quantitative content analysis, one area for future research concerns the method's continued application to trace the spread of ideas over time by examining the content of citations. Studies of this nature provide a different type of information that offers additional insight into complex intellectual histories that, to date, are largely examined by interpretive approaches (Rogers & Dearing, 1993). Another area focuses more generally on the continued exploration of the method's ability to reliably handle varying degrees of latent content. While manifest content is easier to code reliably with independent coders, successful coding of latent content types will likely provide more interesting and in-depth information about the topic in question. A third area for research involves using multiple coding phases to increase intercoder reliability. By dividing the coding teams in this study into two phases—citation coding and article/idea information coding—we reasoned that this would offset the coder fatigue that would have likely resulted if only a single group coded for both the location of the citations as well as the eleven article and idea variables. A future study might compare reliability scores between a single team coding a series of complex variables to the scores of multiple teams coding the same content broken out into different phases in order to determine if this logic holds.

Concluding Remarks

It is doubtful at the time of its writing that Licklider fully understood the foresight contained in, "Man-Computer Symbiosis," nor its potential influence. Decades later, in typical unassuming fashion, Licklider would downplay the insights his article provided stating in an interview that the piece "…didn't come out of any particular research. It was just a statement about the general notion of analyzing work …that you could see exactly how to get a computer to do" (Licklider, 1988, p.22). Unfortunately, Licklider died in 1992, just prior to the Internet's release to the general public in the U.S and the development of the graphical World Wide Web, and did not witness the fuller realization of his "Intergalactic Network" that exists today. Yet reading the article from today's perspective, one is immediately struck by the clarity and detail of Licklider's vision for technological improvements that would lead to the network of computers we now know as "the Internet." And though many may argue, and rightly so, that we still have much to accomplish in the quest for ultimate human-computer symbiosis, we also recognize the enormous strides taken since the publication of "Man-Computer Symbiosis." Graphical user interfaces, the wireless keyboard and mouse, streaming audio and video, gigahertz processors and hard drives in personal computers, virtual reality, programming languages, and the World Wide Web are examples of strides taken to improve the human-computer relationship over the last five decades in the areas specified by Licklider.

The aforementioned examples do not imply that improvements in computer technology are solely beneficial. Licklider himself expressed doubts during his career about the downside of increased integration of computers into our lives, and we see today some of the damaging effects of computing realized—the Digital Divide, toxic environmental pollutants from components manufacturing, viruses and hacking, and increased surveillance, to name a few. On the horizon lurk scenarios that are potentially more dangerous as revealed by computing pioneer Bill Joy (2000), a cofounder and former Chief Scientist of Sun Microsystems, in his dim forecast concerning developments in nanotechnology and artificial intelligence. Joy's article parallels Licklider's 1960 admission that, in time, computers via artificial intelligence (and now also via artificial life) may one day supersede humankind.

Whatever the end result of our attempts to perfect the human-computer relationship, in 1960 well before the technology was available Licklider penned a prescient article outlining a new type of human-computer partnership along with the technological advancements required to get there. He called for a departure from the standard scientific view of computing to promote a paradigmatic shift. As Kuhn (1970) explains, scientific change is a combination of evolution, gradual refinements to existing practices, and revolution, breaks from conventional practices to promote different practices. The major scientific advancements occur as revolutionary events, major departures from previous ways of thinking. These revolutions occur on large and small scales, but they are revolutions all the same. Licklider initiated a revolution when he shared his vision with the research community primarily through interpersonal contacts and secondarily via a scholarly publication that is frequently cited as helping to initiate research in interactive computing.

This study has focused on Licklider's publication as a way to supplement Internet histories and personal accounts of the influential nature of "Man-Computer Symbiosis." Although the small number of articles examined in this study provides a conservative estimate of the article's influence, the results indicate that Licklider's vision diffused widely among this set of individuals helping to promote a research agenda focused on achieving human-computer symbiosis. In reality, "Man-Computer Symbiosis" was not *the* vehicle for communicating Licklider's ideas; rather, it was *a* vehicle that reinforced his interpersonal/informal connections. As Randall (1997) observes, "Licklider directly influenced several of the Internet's early initiators, but his main contribution was his impact on the office of ARPA called the Information Processing Techniques Office (IPTO)" (p. 12). It was in this position as head of IPTO that Licklider was able to fund the very areas of computing that he identified in "Man-Computer Symbiosis" (Licklider, 1988) and to bring together key individuals who could make his vision a reality. Based on the observation of Hafner and Lyon (1996) that the publication of "Man-Computer Symbiosis" sealed his reputation as a credible computer scientist, it is speculated that the credibility generated by the article assisted Licklider in securing the IPTO position.

"Man-Computer Symbiosis" succinctly communicated the gist of several years' worth of contemplation by Licklider and served to function as a common thread sewing together separate areas of computer research—timesharing, hardware, software, language, and input/output devices—to encourage an increased dialogue between researchers in these different areas. Nine years after the article's publication, an experimental technology emerged based, in part, on this published vision: ARPAnet, the Internet's forerunner (Taylor, 1989). For "Man-Computer Symbiosis" the diffusion process continues today in a slow but steady fashion among respected authors, research journals, and institutions. The article is still cited in the science and technology literatures, and it appears to be making its way increasingly into the humanities and social sciences literatures—an indicator of the article's subtle but ongoing contribution to Internet and, more generally, human-computer research.

APPENDIX A

A1: ISI CITED REFERENCE SEARCH RESULTS FOR "MAN-COMPUTER SYMBIOSIS"

ISI cited reference search results for "Man-Computer Symbiosis" conducted 12/14/2002, depicting variations in how the article has been cited (as originally formatted by ISI).

Full citation:
Licklider, J. C. R. (1960). Man-computer symbiosis. *IRE Transactions on Human Factors in Electronics*, *HFE-1*, 4-11.

Hits	Cited Author	Cited Work	Volume	Page	Year
1	LICKLIDER	IRE T HUMAN FACT MAR			1960
1	LICKLIDER J	T HUMAN FACTORS ELEC	1	4	1960
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2	LICKLIDER JCR	IRE T HUM FACT ELECT	11	4	1960
1	LICKLIDER JCR	IRE T HUM FACT ELECT	1	5	1960
1	LICKLIDER JCR	IRE T HUM FACTORS EL	1		1960
59	LICKLIDER JCR	IRE T HUM FACTORS EL	1	4	1960
1	LICKLIDER JCR	IRE T HUM FACTORS EL	1	PA11	1960
2	LICKLIDER JCR	IRE T HUMAN FACT MAR			1960
19	LICKLIDER JCR	IRE T HUMAN FACT MAR		4	1960
1	LICKLIDER JCR	IRE T HUMAN FACTORS	1	4	1961
2	LICKLIDER JCR	IRE T HUMAN FACTORS			1960
1	LICKLIDER JCR	IRE T HUMAN FACTORS	4		1960
3	LICKLIDER JCR	IRE T HUMAN FACTORS	2	4	1960
1	LICKLIDER JCR	IRE T HUMAN FACTORS	1		1960
2	LICKLIDER JCR	IRE T HUMAN FACTORS	HFE1		1960
24	LICKLIDER JCR	IRE T HUMAN FACTORS	HFE1	4	1960
1	LICKLIDER JCR	MAN COMPUTER SYMBIOS			
1	LICKLIDER JCR	MAN COMPUTER SYMBIOS			1960
1	LICKLIDER JCR	MAN COMPUTER SYMBIOS		132	1960
1	LICKLIDER JCR	MAR IRE T HUM FACT E			1960
1	LICKLIDER JCR	MAR IRE T HUM FACT E		4	1960

129 total articles

A2: ISI CITED REFERENCE SEARCH RESULTS FROM 12/04/2002

Articles are listed in descending order, as originally presented in the ISI search results, by the year of the citing article. Author names are alphabetized within in each year's grouping. The bracketed number at the end of each reference is the article identification number used for coding purposes.

Total articles: 129

2001

Scallen, S. F. & Hancock, P. A. (2001). Implementing adaptive function allocation. *International Journal of Aviation Psychology, 11 (2)*, 197-221. [129]

Stanton, N.A. (2001). Introduction: Ubiquitous computing: Anytime, anyplace, anywhere? *International Journal of Human-Computer Interaction, 13(2)*, 107-111. [128]

Walker, G. H., Stanton, N. A., & Young, M. S. (2001). Where is computing driving cars? *International Journal of Human-Computer Interaction, 13 (2)*, 203-229. [127]

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Witten, I. H. (2000). Browsing around a digital library: Today and tomorrow. In *Combinatorial Pattern Matching: Vol. 1848. Lecture Notes in Computer Science* (pp. 12-26). [124]

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A3: EXPLANATION OF ARTICLES REMOVED FROM CODING

Total articles omitted: 19

Non-English articles

[048] Kirsch, W., & Kieser, H. P. (1974). Perspectives of consumer adequance of management-informations-systems. *Zeitschrift fur Betriebswirtschaft, 44(6),* 383-402.

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APPENDIX B

JOURNAL SUBJECT CLASSFICATION

Library of Congress (LOC) subject classification of journal titles identified by citation analysis. Entries are arranged alphabetically according to Specific Subject column.

Journal	**Call Number**	**General Subject***	**Specific Subject**	**Subclass**	**# of Articles**
American Documentation	Z1007 A477	Sciences	Bibliography. Library Science. Information Resources.	General bibliography.	1
Annual Review of Information Science and Technology	Z699 A1 A65	Sciences	Bibliography. Library Science. Information Resources.	Machine methods of information and retrieval. Mechanized bibliographic control.	2
Database	Z699 A1 D37	Sciences	Bibliography. Library Science. Information Resources.	Machine methods of information and retrieval. Mechanized bibliographic control.	1
Journal of the American Society for Information Science	Z1007 A477	Sciences	Bibliography. Library Science. Information Resources.	General bibliography.	1
Online	Z699 A1 O54	Sciences	Bibliography. Library Science. Information Resources.	Machine methods of information and retrieval. Mechanized bibliographic control.	1
Online Review	Z699 A1 O5	Sciences	Bibliography. Library Science. Information Resources.	Machine methods of information and retrieval. Mechanized bibliographic control.	1
Proceedings of the American Society for Information Science	Z1008 A4616	Sciences	Bibliography. Library Science. Information Resources.	General bibliography.	1
American Scientist	LJ85 S502	Social Sciences	Education	Student fraternities and societies. United States	1
Anthropology UCLA	GN1 C29	Humanities	Geography. Anthropology. Recreation.	Anthropology	1

Journal	Call Number	General Subject*	Specific Subject	Subclass	# of Articles
Journal of Social and Evolutionary Systems	GN365.9 J68	Humanities	Geography. Anthropology. Recreation.	Anthropology. Culture and cultural processes – including social change, diffusion, social reform.	2
American Historical Review	E172 A672	Humanities	History: America	History. United States. General.	1
Arachne	PN9 A72	Humanities	Language & Literature	Literature. Periodicals.	1
Communication Theory	P87 C59737	Humanities	Language & Literature	Communication. Mass media	1
Journal of Communication	P87 J6	Humanities	Language & Literature	Communication. Mass Media	1
Documenta Ophthalmologica	RE14 D6	Sciences	Medicine	Ophthalmology	1
IEEE Transactions on Biomedical Engineering	R895 A1 I25	Sciences	Medicine	Medical physics. Medical radiology. Nuclear medicine	1
Journal of Occupational and Environmental Medicine	RC963 A42	Sciences	Medicine	Industrial medicine. Industrial hygiene	1
IEEE Transactions on Military Electronics	UG485 I2	Sciences	Military Science	Military engineering.	1
American Psychologist	BF1 A55	Humanities	Philosophy. Psychology. Religion.	Psychology	1
Behavior Research Methods & Instrumentation	BF180 B4	Humanities	Philosophy. Psychology. Religion.	Psychology. Experimental psychology	1
British Journal of Psychology	BF1 B7	Humanities	Philosophy. Psychology. Religion.	Psychology	1
Ceskoslovenska Psychologie	BF8 C9 C4	Humanities	Philosophy. Psychology. Religion.	Psychology	1
Journal of Applied Psychology	BF1 J55	Humanities	Philosophy. Psychology. Religion.	Psychology	1
Journal of Phenomenological Psychology	BF204.5 J68	Humanities	Philosophy. Psychology. Religion.	Psychology. Gestalt psychology	1
Semiotica	B820 S45	Humanities	Philosophy. Psychology. Religion.	Philosophy. Modern	1
Ultimate Reality and Meaning	BD331 U43	Humanities	Philosophy. Psychology. Religion.	Speculative philosophy. Ontology	1
Abacus	QA75.5 A13	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Advances in Computers	QA76 A3	Sciences	Science	Mathematics. Electronic computers. Computer science	2

Journal	Call Number	General Subject*	Specific Subject	Subclass	# of Articles
Annals of the New York Academy of Sciences	Q11 N5	Sciences	Science	Science. General	1
Communications of the ACM	QA75.5 A138	Sciences	Science	Mathematics. Electronic computers. Computer science	6
Computer Bulletin	QA76 C56	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Computer Journal	QA76 C57	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Computing Surveys	QA76.5 C617	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Daedalus	Q11 B7	Sciences	Science	Science. General	1
IEEE Annals of the History of Computing	QA76.17 A56	Sciences	Science	Mathematics. Electronic computers. Computer science	6
IEEE Transactions on Systems Man and Cybernetics	Q300 I43	Sciences	Science	Science. Cybernetics	5
Information and Decision Technologies	QA402 L357	Sciences	Science	Mathematics. Analysis	1
International Journal of Human-Computer Interaction	QA76.9 H85 I62	Sciences	Science	Mathematics. Electronic computers. Computer science	2
Lecture Notes in Computer Science	QA76.9 A25 C78a	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Lecture Notes in Computer Science	QA267 A66	Sciences	Science	Probabilities. Mathematical statistics.	1
Oxford Surveys in Information Technology	QA75.5 O93	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Science	Q1 S35	Sciences	Science	Science. General	1
Sigplan Notices	QA76.7 S54	Sciences	Science	Mathematics. Electronic computers. Computer science	1
Social Studies of Science	Q1 S82	Sciences	Science	Science. General	1
Ekistics	HN1 E45	Social Sciences	Social Sciences	Social history and conditions. Social problems.	1
Futures	HB3730 F8	Social Sciences	Social Sciences	Economic theory. Demography.	1
Industrial Management Review – IMR/ Sloan Management Review	HD28 I14	Social Sciences	Social Sciences	Industries. Land Use. Labor. Management. Industrial Management.	2

Journal	Call Number	General Subject*	Specific Subject	Subclass	# of Articles
Journal of Systems Management	HD28 S953	Social Sciences	Social Sciences	Industries. Land Use. Labor. Management. Industrial Management.	1
Management Science	HD28 I453	Social Sciences	Social Sciences	Industries. Land Use. Labor. Management. Industrial Management.	1
Organization	HM131 O667	Social Sciences	Social Sciences	Sociology. General	1
Zeitschrift fur Betriebswirtschaft	HD28 Z45	Social Sciences	Social Sciences	Industries. Land Use. Labor. Management. Industrial Management.	1
AIIE Transactions	T55.4 A5	Sciences	Technology	Technology. Industrial Engineering. Management Engineering.	1
Applied Ergonomics	TA166 A66	Sciences	Technology	Engineering. Human Engineering.	2
AT&T Bell Laboratories Technical Journal	TK1 B425	Sciences	Technology	Electrical Engineering. Electronics. Nuclear Engineering.	1
Computer	TK7885 A1 I5	Sciences	Technology	Computer Engineering. Computer Hardware.	1
Computers and People/Computers and Automation	TJ212 C58	Sciences	Technology	Mechanical Engineering and Machinery. Control Engineering Systems. Automatic machinery.	2
Ergonomics	TA166 E7	Sciences	Technology	Engineering. Human Engineering.	5
Human Factors	T58 A2 H8	Sciences	Technology	Technology. General	9
Human Factors and Ergonomics in Manufacturing	TS155.6 I5935	Sciences	Technology	Manufactures. Production management. Operations management	1
IEEE Spectrum	TK1 I15	Sciences	Technology	Electrical Engineering. Electronics. Nuclear Engineering.	2
IEEE Transactions on Electron Devices	TK7870 I2	Sciences	Technology	Electronics	1
IEEE Transactions on Electronic Computers	TK7885 A1 I2	Sciences	Technology	Computer Engineering. Computer Hardware.	2
IEEE Transactions on Engineering Management	T56 I2	Sciences	Technology	Industrial Engineering. Management Engineering.	2
IEEE Transactions on Human Factors in Electronics/ IRE Transactions on Human Factors in Electronics	TA166 I2	Sciences	Technology	Engineering. Human Engineering.	3
IEEE Transactions on Industry and General Applications	TK1 I39	Sciences	Technology	Electrical Engineering. Electronics. Nuclear Engineering.	1
IEEE Transactions on Nuclear Science	TK9001 I2	Sciences	Technology	Nuclear Engineering	1

Journal	Call Number	General Subject*	Specific Subject	Subclass	# of Articles
IEEE Transactions on Systems Science and Cybernetics	TA168 I22	Sciences	Technology	Engineering. Systems Engineering.	1
International Journal of Aviation Psychology	TL553.6 I57	Sciences	Technology	Aeronautics. Aeronautical Engineering.	1
International Journal of Human-Computer Studies/ International Journal of Man-Machine Studies	TA167 I5	Sciences	Technology	Engineering. Human Engineering.	11
Journal of Industrial Engineering	T55.4 J68	Sciences	Technology	Industrial Engineering	1
Microelectronics and Reliability	TK7870 M456	Sciences	Technology	Electronics	1
Proceedings of the IEEE/ Proceedings of the Institute of Radio Engineers	TK5700 I6	Sciences	Technology	Telecommunication	7
Scientific American	T1 S5	Sciences	Technology	Technology. General	1
Simulation	TA343 S52	Sciences	Technology	Engineering mathematics. Engineering analysis.	1
Travail Humain	T58 A2 T7	Sciences	Technology	Technology. General	1

* General Subject is researcher defined

Total **129**

Abbreviations

ACM = Association for Computing Machinery
AIIE = American Institute of Industrial Engineers
IEEE = Institute of Electrical and Electronics Engineers
IRE = Institute of Radio Engineers

APPENDIX C

C1: CITATION IDENTIFICATION CODING PROCEDURES

General Guidelines

1. You are coding articles for the presence of in-text citations to J. C. R. Licklider's, "Man-Computer Symbiosis"(1960) publication. The full reference for the article is:

   Licklider, J. C. R. (1960). Man-computer symbiosis. *IRE Transactions on Human Factors in Electronics*, *HFE-1*, 4-11.

2. Read the coding steps listed below each time you begin a coding session.
3. Take at least a 10 minute break after coding 10 articles or 1 hour, whichever occurs first. Even if you don't feel tired, take at least a 10 minute break before continuing to code and re-read the coding rules before starting.
4. Keep all food and beverage items away from the articles. If an article gets damaged from a food or beverage item, you will be responsible for replacing the article.
5. Turn in your coding by the assigned deadline.

STEP 1

For each article, **locate the reference list at the end of the article** (if it exists). There are three reasons for doing this:

1. Locating the reference list allows you to verify that "Man-Computer Symbiosis" is cited in the article.
2. Alerts you to other articles written by Licklider that are also cited. You will want to make sure that you only code those citations that reference "Man-computer Symbiosis."
3. Informs you of the citation style being used (e.g., APA, MLA, Chicago) so that you know more clearly and can more readily identify the citation format.

   General rules

   - APA uses parenthetical in-text citations: (Licklider, 1960); Licklider (1960); Man-computer Symbiosis (1960)
   - MLA uses parenthetical citations, footnotes (numbered and located at the bottom of a page), and sometimes endnotes (numbered and located at the end of the article)
   - Chicago uses footnotes and endnotes.
   - Some journals specify their own citation style. Looking at the reference list can help you to identify the style.

   <u>Notes</u>

STEP 2
Scan the entire article to locate in-text references to "Man-computer Symbiosis." Additional guidelines:

- Only mark **formal citations** to "Man-computer Symbiosis." Mark only those instances where the citation is in the form of a footnote, endnote, parenthetical format, or specifies Licklider and/or "Man-Computer Symbiosis."
- If you need to do a line by line scan of the article to locate citations, use a blank piece of paper to guide your eyes. You are less likely to miss citations this way.
- If an initial scan does not reveal a citation, perform a second scan before concluding that one does not exist.

Notes

C2: ARTICLE INFORMATION AND IDEAS CODE BOOK

I. GENERAL ARTICLE INFORMATION

Instructions: Each article has a unique identifier number (e.g., 001) and its own set of coding sheets. Be sure to verify that the article number matches the number listed on the coding sheet before you start to code.

Some of the variable information for each article will already be filled in on the coding sheet. In these cases, you are simply to read carefully to check that the article information matches with what is on the coding sheet. If there are any discrepancies between the article and coding sheet information, make corrections to the coding sheet information.

For Coder # write in the first letter of your first name.

V1. ***Author(s)***

Verify first author name provided by citation analysis; note any corrections on the coding sheet. Record any additional author names.

Code author name(s) as follows: *last name*, *first name*, *middle name*

V2. ***Author position***

The *current* position held by each author is usually contained in a brief biographical sketch at the beginning or end of an article (usually in a footnote format). If an individual holds two positions, for example, a faculty position and a CEO position, record both a "1" and a "2" for this variable (e.g., 1, 2)

Record the rank (e.g., the position held) by each author as follows:

Academy	=	1
Private sector	=	2
Government	=	3
Other	=	4 (*write in position as reported in article*)
Not specified/unclear	=	5

V3. ***Institutional Affiliation***

The *current* institution that each author is affiliated (employed by) with is usually contained in a brief biographical sketch at the beginning or end of an article (usually in a footnote format). We are not interested in professional memberships such as, "IEEE Member." We are only interested in where the author *currently* is employed at the time of the article's publication, not previous places of employment. If an author is affiliated with more than one organization, record both places.

Continued on next page.

Record institution affiliation as follows:

Abbreviate "University" or "University of" as "U"
Abbreviate state names using the standard postal code abbreviations
Spell out all corporation titles (e.g., International Business Machines (IBM))
For non-U.S. universities, write in the complete name

Examples:

University of Arizona	=	U AZ
Florida State University	=	FL St U
Stanford University	=	Stanford U
University of Copenhagen	=	U Copenhagen
Digital Equipment Corporation	=	Digital Equipment Corp

If no institutional information is provided, write in *None*

V4. ***Year of publication***

Verify the full year of the publication: 1963, 1975, 2001, etc., noting any corrections on the coding sheet.

V5. ***Journal***

Verify the journal title provided by the citation analysis. Note any corrections on the coding sheet.

Coding information continued on the next page.

II. "MAN-COMPUTER SYMBIOSIS" (MCS) INFORMATION

Instructions: Each article already has the in-text citation(s) to Licklider's "Man-Computer Symbiosis" identified for you, and each citation within an article has a unique identifier number (e.g., 001-A). Match the citation identifier number with the one listed on the coding sheet before you code.

For each citation identified, 1) read the sentence(s) containing the citation(s). If the citation sentence alone is too vague to make coding decisions then, 2) read the sentence immediately preceding and immediately following the citation; do this also to be certain that the author does not go on to elaborate on the citation. If the immediately surrounding sentences are still too vague for you to make coding decisions, 3) read the entire paragraph in which the citation appears and make your coding decisions. Try not to over think the meaning of a citation—go with your first instinct and move on.

Code for the following:

PART A. Reference to the *general idea* of the human-computer relationship; record the presence or absence of:

V6. ***Symbiosis***

Code for the presence of *Symbiosis* if:

- Any general reference is made to Licklider's basic idea of a *symbiotic* relationship between humans and computers.
  Record the presence of symbiosis if any reference is made to the term *symbiosis* and its variations *symbiotic*, *symbiotical*, *symbiotically*, *symbiont*, and *symbiote*.

- Only a general reference (e.g., title only) is made to the article.

- General reference is made to a *mutually beneficial* (e.g., cooperative thinking) or a *potentially negative* (e.g., replacement/domination of humans by computers) relationship between humans and computers.

- Any reference exists to terms such as:
  - fig tree and wasp scenario
  - partnership
  - mechanically extended man
  - relationship
  - interactive computing
  - interaction
  - human computer interaction (HCI)
  - fusion
  - cooperation/cooperative
  - coupling
  - problem-solving/formulative thinking/real-time thinking

Absent	=	0
Present	=	1

PART B. References to *specific improvements* to computer technology as outlined in "Man-Computer Symbiosis"; record the presence or absence of each:

V7. ***Speed Mismatch Between Men and Computers***

Code for the presence of *Speed mismatch* if:

- There is reference to any *internal differences* in human and computer processing abilities.
  - Complexity of human thought vs. speed of computer processing/calculating.

- There is any reference to the following:
  - processing
  - multi-tasking
  - time-sharing
  - task allocation
    - The four terms above tie into the idea of use of a computer system by more than one individual at the same time. Also includes any reference to how a computer runs separate programs simultaneously by dividing up processor time between programs and/or users.
  - computer response time (CRT)
  - networks
  - automated libraries/"thinking centers" (predicted "10 to 15 years hence")
  - wideband communication lines linking users via leased-wire services
  - Licklider's experiment in which 85% of his time was spent preparing to work

Absent	=	0
Present	=	1

V8. ***Memory Hardware*** Emphasizes *physical memory components.*

Code for the presence of *Memory hardware* if:

- There is any reference to the data *storage medium* of a computer.
  - May refer specifically to the *physical* memory components such as hard drives, floppy disks, short term and long term memory and so on.

- There is any reference to the following:
  - magnetic disks
  - core, thin film, or tape memory
  - selection circuitry
  - drums
  - RAM and/or ROM; *indelible memory* and/or *published memory*
  - hard disks/drives
  - floppy disks, zip disks, CD/DVD ROMs
  - general reference to the term "memory"

Absent	=	0
Present	=	1

V9. ***Memory Organization*** Emphasizes the *software* aspect of memory.

Code for the presence of *Memory organization* if:

- There is any reference to how a user *navigates* a computer to access data/information (e.g., via folders that store files, "point and click").
    - Or any reference to *procedures* or *rules* that a computer uses to store/retrieve data.

- There is any reference to the following:
    - data storage techniques
    - computer interface design/graphical user interface (GUI)
    - computer search tools (e.g., "find" command, search engines)
    - name and/or pattern searching
    - "trie memory" (branching storage structure resembling a tree)
    - general reference to the term "memory"

Absent	=	0
Present	=	1

V10. ***The Language Problem***

Code for the presence of *The language problem* if:

- There is any reference made to the *dissimilarity* between human language and computer language.
    - An issue of *communication* differences between humans and computers.
    - Computers use electric impulses (on/off, 1s and 0s) while humans use words and symbols. This creates a communication barrier that is overcome, in part, by programming languages.

- There is any reference to the following:
    - computer language/machine language
    - natural language (humans)
    - assembly and/or compiling programs
    - programming languages
        - Fortran
        - Basic
        - Perl
        - C++ (and other specific names of languages)
    - instructions directed to *computers* specifying *courses* (i.e., performing specific steps in a specific sequence)
    - instructions directed to *human beings* specifying *goals* (i.e., performance based on incentives or motivations to accomplish a task and to know when a task is complete)

Absent	=	0
Present	=	1

V11. *Input/output equipment*

Code for the presence of *Input/output equipment* if:

- There is any reference to the *physical components* of a computer that allow the user to *enter data* or to *produce a copy* of that data/information.

- There is any reference to the following computer components:
  - general reference to computer displays and/or controls
  - keyboard
  - mouse
  - monitor/console/screen/flat panel screen
  - wall-sized screen displays
  - light pen
  - touch screen
  - printer
  - scanner/copier
  - digital fax machine
  - virtual reality gloves and goggles
  - joystick
  - microphone
  - speakers
  - CD/DVD drive/burner
  - floppy/zip drive
  - modem
  - speech recognition/production/vocabulary of words

- There is any reference to other technologies that were/are as good as or better than the computer:
  - typewriter
  - pencil and doodle/sketch pad or paper
  - chalk and blackboard/chalkboard
  - hand calculator/adding machine

Absent	=	0
Present	=	1

End of code book.

C3: CODING SHEET

CODER#: _________

GENERAL ARTICLE INFORMATION

Article #		**Author Position** (V2)	**Institutional Affiliation** (V3)
Author (first) (V1)			
Additional authors (in the order that they appear)			
Publication Year (V4)			
Journal (V5)			

"MAN-COMPUTER SYMBIOSIS" (MCS) INFORMATION

Citation #	
References to Ideas	**Presence or Absence**
Symbiosis (V6)	
Speed mismatch (V7)	
Memory hardware (V8)	
Memory organization (V9)	
The language problem (V10)	
Input/output equipment (V11)	

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BIOGRAPHICAL SKETCH

Ms. Tomasello was born in Coral Gables, Florida and has since lived in a variety of locations including Connecticut, Michigan, Ohio, South Carolina, and Virginia. Degrees held include a Bachelor of Architecture with a minor in Communication from Virginia Tech (1997), a Master of Science in Communication with an emphasis in Mass Communication from Florida State University (2000), and a Doctor of Philosophy in Communication with an emphasis in Research and Theory from Florida State University (2004). Professional experience includes nine years in a Tier I academic research library in technical services (e.g., receiving, cataloging) and user services (e.g., reference, inter-library loan). Ms. Tomasello intends to continue researching and teaching in the area of new communication technologies focusing on social, political, and historical subjects related to the ideal of equal access to networked communication and information resources.