Title
Social Science: Complex Cognition in Early AIDS Research

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 30(30)

ISSN
1069-7977

Authors
Lippa, Katherine D.
Shalin, Valerie L.

Publication Date
2008

Peer reviewed

Social Science: Complex Cognition in Early AIDS Research

Katherine D. Lippa (lippa.2@wright.edu)
Department of Psychology, 3640 Colonel Glenn Hwy
Dayton, OH 45435 USA

Valerie L. Shalin (valerie.shalin@wright.edu)
Department of Psychology, 3640 Colonel Glenn Hwy
Dayton, OH 45435 USA

Abstract

AIDS presented a totally unknown disorder requiring immediate solutions. This study examines how leading scientists studied and thought about AIDS during the first years of the epidemic. We present a detailed analysis of three interviews with scientists who worked at or with the National Institutes of Health. Though representing different disciplines (epidemiology, clinical work, & immunology), the scientists went through similar stages in their thinking. An initial data gathering stage characterized by inductive logic was followed by an explanatory phase using abduction to understand the initial results and generate hypotheses. And finally a deductive stage where the data from the different scientists were combined to help discover the HIV virus as the underlying cause of AIDS. We highlight the discipline-specific manner in which each researcher engaged with the problem, the role of abduction and the influence of the scientists on each other's reasoning.

Keywords: scientific reasoning, medical reasoning, analogical reasoning, cognitive-historical analysis, logical processes, AIDS

"Pneumocystis Pneumonia – Los Angeles" (Gottlieb, et al., 1981) these words headed a brief article disseminated to virtually every medical facility in the United States. The brief, apparently un-alarming report described five cases of a rare condition in a distrusted minority. It was also the first announcement of what would become the most deadly epidemic in modern times - AIDS.

The early years of AIDS present a unique opportunity to study how scientists solve complex, novel problems. Most cognitive science research on scientific reasoning has either examined the historical records pertaining to specific individuals making exceptional discoveries or has used experimental and/or computational techniques to analyze some aspect of individual reasoning (Klahr & Simon, 1999). Both types of research have strengths and limitations.

Until quite recently, studies based on historical records have tended to examine single individuals. The sudden appearance of AIDS presented the same information at the same time to many scientists from different disciplines. As such, AIDS provides an opportunity to compare reasoning among individuals and to see how the interactions among disciplines contributed to problem solving.

A hypothetical-deductive model of science popular with philosophers in the mid 20th century (Popper, 1959) appears to inform most laboratory experiments on scientific reasoning in cognitive science. Perhaps a broader perspective on reasoning will identify processes not apparent in pre-focused laboratory research. Examining real world cases, like AIDS research provides an opportunity for a richer picture of scientific reasoning to emerge.

The research reported here examines reasoning by several influential figures in early efforts to combat AIDS. It evaluates both their unique reasoning processes and how they interacted with one another to gain critical insights and make discoveries.

Methods

In this study, we apply cognitive-historical analysis (Nersessian, 1992), which approaches scientific reasoning by examining historical documents with an analytic lens grounded in cognitive science.

Data

The primary data source was a series of post hoc interviews with early AIDS researchers who were working with the National Institutes of Health (NIH) (NIH, n.d)[1]. Victoria Harden conducted these interviews between 1988 and 1998. Ten interviews were selected for analysis that were primarily concerned with clinical or laboratory research (as opposed social or administrative issues), addressed the interviewee's thinking regarding some issue relevant to early research, and addressed the interviewee's own thoughts and experiences rather than their recollections of what others were doing. Preliminary analysis raised two methodological problems. First, many of the studies were shared efforts by several researchers (e.g. 3 researchers spent time in the same laboratory group), creating redundancy. Second, the data set was unmanageably large, making it difficult to see patterns. Therefore, we focused on three researchers, Dr. James Curran, Dr. Thomas Waldmann, and Dr. Anthony Fauci, for detailed analyses. These three were selected because they represented different disciplines and they headed efforts that involved most of the other researchers. Curran was working as an epidemiologist at the Centers for Disease Control (CDC) in Atlanta and headed their task force on AIDS. Waldmann was a researcher at the NIH in Bethesda, but his involvement with AIDS was primarily clinical, having the

[1] This study is limited by the post hoc nature of the data. A more extensive study is planned with a larger data set and incorporating contemporary documents (e.g. memos and scientific papers).

first AIDS patient to come to the NIH in his service. Fauci, an immunologist, was the first researcher at the NIH to devote his lab to AIDS research. The contributions of these three researchers linked to the thinking of a forth researcher, Dr. Robert Gallo (NIH), whose discovery of HIV caps this early period of research. By tracing how these three researchers developed insights leading to Gallo's work we were able to see how their unique contributions came together to create a cohesive whole.

Other documents were used to support the statements made in the interviews including journal articles published by or referred to by interviewees, *Morbidity and Mortality Weekly Report*s published by the CDC, and a small number of memos circulated through the NIH at that time.

Coding

The interviews were first coded for reasoning processes and content. The codes were used to create concept maps illustrating the reasoning of the researchers individually and in interaction with each other. These maps facilitated the identification of critical points and trends.

Coding occurred in two phases. First an emergent coding method, based on principles of grounded theory, captured major modes of reasoning and content (Bohm, 2004). This coding scheme was simplified by merging overlapping codes and eliminating infrequent codes. All transcripts were recoded by two coders. The codings were compared and instances of disagreement were resolved by discussion until consensus. From the consensus coding three additional codes were eliminated because of near total correlation with other codes (e.g. 'information seeking' was eliminated because it always accompanied the 'action'). The final coding scheme included four reasoning codes, induction, deduction, abduction, and analogical reasoning, and three content codes, action, belief, and information; see Table 1. Coding was facilitated using Atlas.ti© (Atlas.ti, 2008).

Mapping

Banxia Decision Explorer© was used to create cognitive maps of the researchers' reasoning from the coded transcripts (Banxia, 2005). Each of the content codes became a node and each of the reasoning codes became a link. An additional kind of arrow was added: a directional link indicating that one thing leads to another (usually an action leading to a piece of information obtained via the action). Each node has a unique identifying number; which directs attention to specific nodes in the discussion below. To represent interactions between researchers, the researchers' individual maps were connected at nodes that were common to both maps. For example, Curran's work led him to believe AIDS was caused by an infectious agent (node 396).

Table 1: Coding examples.

Code	Example
Induction	"cases of Kaposi's sarcoma, … cases of opportunistic infections …. paralleled each other. They were all going up; they were all in the same age groups; they were all in the same places. So this was really one epidemic."
Deduction	"When you deal with infections that are sexually transmitted and blood borne, … there is no reason to believe they will stay confined … because sex is a universal … and people donate blood"
Abduction	"Since there was a seemingly selective defect in CD4-positive T cells, there was much speculation that we were dealing with a retrovirus…"
Analogical reasoning	"it was going to be in the blood supply if it were caused by a virus like hepatitis B"
Action	"We did another study-it was a cluster analysis-that began in 1982"
Belief	"we were dealing with something that was going to be a disaster"
Information	"their B cells were inappropriately hyperactive"

This belief was shared by Fauci and was a critical factor in his assessment of the disease as serious and motivation to study it. So Curran's and Fauci's maps were connected at the shared belief node. The map was pared down so that only those nodes and links that included significant information or influenced later reasoning were retained. This map is shown in Figure 1.

Description

Finally, an enriched description of the trends and patterns observed in the maps was created by combining simplified maps used for illustrative purposes with selected quotations. This description is presented below.

Results

Although the researchers approached AIDS from different disciplines, they passed through similar structural stages. In the first stage, the researchers had to take ownership of the problem by realizing that it was serious and that they could contribute to a solution. In the second stage, they had to define the parameters of the problem by making extensive observations and using induction to create a profile for the disease. Next, from the perspective of their disciplines, the researchers used abduction to come up with causal hypotheses. Finally, all of these beliefs converged to convince Gallo that a retrovirus was the underlying cause. This pattern is illustrated in Figure 1.

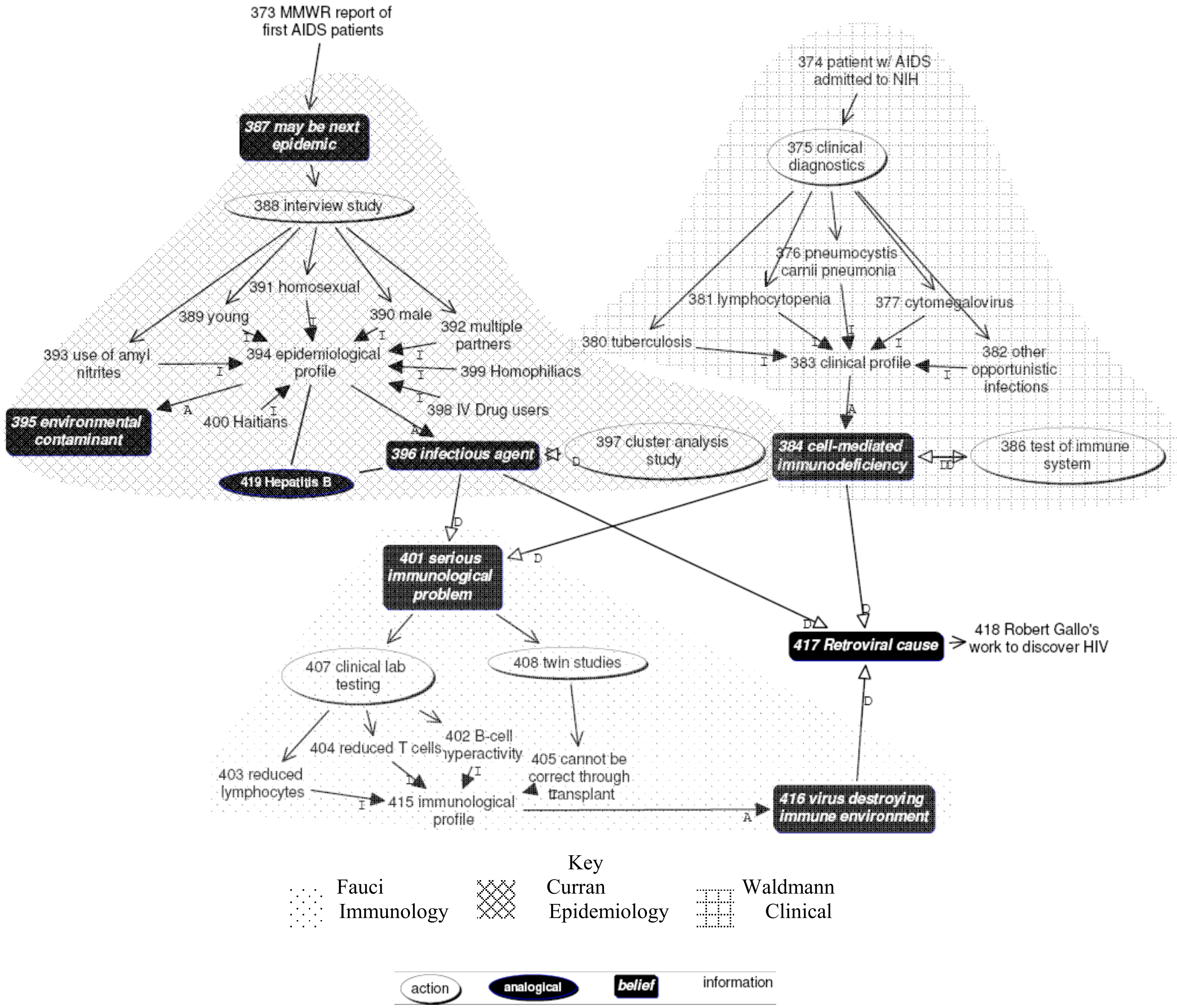

Figure 1. Map of reasoning across three scientists

The First Report: Problem Ownership

A mixed reaction greeted the first report of what would come to be known as AIDS. Some people realized it represented a potential threat, while others failed to notice or dismissed it. The degree of resulting action by individuals within the sample depended upon whether they perceived the reported as relevant to them or their research. They had to take ownership of the problem by realizing that it a) mattered and b) fell within their domain (Shalin & Bertram, 1996). The three researchers targeted in this study each took action in a way that was characteristic of their disciplines.

Curran, the epidemiologist, was working at the CDC and saw a draft of the first report before it was published. He consulted with colleagues and looked for additional cases. When the report was published, he headed the task force to deal with the problem. Immediate concern for the disease as an emerging threat led to a quest for further information: "initially, it was thought that these unusual cases might be the next epidemic for the CDC to address. Scientists from different disciplines convened to talk ... It was agreed that we needed to find out more." This movement directly from the 1st report to perceived threat to action, is represented by the direct connections between nodes 373, 387, and 388.

Waldmann's involvement was clinical. He missed the first report. When later that month a patient with strangely varied opportunistic infections showed up at the NIH in his service (node 374), he had no frame of reference for understanding the problem. Like most of the first clinicians to deal with AIDS, he had a patient with an unknown illness. While Waldmann engaged with AIDS on a clinical level he chose not to devote his research to it. This decision was based on the fact that he was uniquely suited to work on problems in other areas and felt that other scientists, including Fauci, were more suited to this area.

Fauci, the immunologist, recalled reading the first report and having two theories about what it represented (a bad drug reaction or a virulent strain of *cytomegalovirus*). He dismissed the issue: "I put the idea to the back of my mind." As an immunological researcher, neither a drug reaction nor a virulent virus was within his purview.

Fauci's eventual involvement was prompted by conclusions from prior research. The beliefs formulated by Curran and Waldmann (described below) that AIDS was an immunodeficiency disorder transmitted by blood and sex led Fauci to be interested in AIDS. An immunodeficiency fell within his domain; the modes of transmission suggested to him that it would spread and be a serious threat. "I said, 'My goodness. This could be an infection that is transmitted by blood and by sex, and I do not have the foggiest idea of what it is.'" This is shown by the connection between Curran's and Waldmann's conclusions (nodes 396 & 384) and Fauci's assessment of the situation (node 401). At this point Fauci became committed to studying AIDS and began to transition his lab entirely to AIDS related work. This was a drastic measure and Fauci described being concerned that "people might think that I was a little strange switching my laboratory over to the study of a new and strange disease." Possibly to support his decision, he published a summary of current knowledge of AIDS and argued for the probable seriousness of the disease (Fauci, 1982).

Initial Observations: The Inductive Phase

Knowing little about the disease, the first researchers used whatever methods their disciplines offered to search for information. As this information became available scientists drew together findings inductively to form domain specific profiles of the disease.

Epidemiology is concerned with who contracts a disease and why. In an effort to answer these questions, Curran and his team set out to track every case of the disease. Luckily one common manifestation of the disease, *pneumocystis carnii*, was treated with a rare drug that had to be specially requested. Using drug requests as a marker, Curran's team located previously unidentified cases. As epidemiologists, they looked for characteristics people with the disorder had in common to identify potential causes. "We wanted to talk to as many living patients as we could. We devised a questionnaire, 30 pages or something, and flew out to talk to every living patient that we could find." This effort is represented in node 388. The profiling effort produced detailed information that was combined inductively to characterize the patient population (nodes 389-393): "the average age of patients was 35 … all of the patients were gay men, and they were living in areas of high opportunity for gay men…They seemed to have large numbers of partners, and they were getting a rare condition…They all went to the same clubs. Most of them used poppers or isobutyl nitrite or amyl nitrite, and they may have been exposed to other things in their environment." The two unusual characteristics of the patient population were their sexual orientation and their use of drugs.

Waldmann was engaged as a clinician, because he had a patient who required care. Since no underlying diagnosis was available, Waldmann and his colleagues created a clinical profile of the patient. This consisted of cataloguing the many opportunistic infections from which the patient suffered (nodes 376-382): "…he had *Pneumocystis carnii* pneumonia, *lymphocytopenia*, *cytomegalovirus* [CMV] in the blood and urine, *herpes simplex II* perianaly, *Candida esophagitis*, and *Mycobacterium avium* tuberculosis of the lung, bone marrow, and esophagus." In retrospect, the profile of this patient proved typical of AIDS.

Fauci's immunology lab began bringing patients to the NIH to study. They ran the fundamental laboratory tests (node 407), which showed reduced T-cells counts and that the B-limb of the immune system was hyperactive even though the patient was immune deficient (nodes 402-404). Fauci also experimented with potential therapeutic interventions. One of his first patients was an identical twin. This allowed him to attempt a bone marrow transplant to reconstitute the immune system (node 408). These efforts failed (node 405) though contributed to Fauci's later reasoning described below. Fauci combined the results of the laboratory tests and the transplant attempts to develop an immunological profile of these patients; they were immune deficient but with abnormal activations of certain components of the immune system and their immunological functioning could not be restored via transplant.

Formation of Core Beliefs: Abduction, Analogy, and Hypothesis Testing

With a disease profile in hand, the researchers tried to explain what could cause such a pattern to occur. Abduction is a posteriori inference of a potential cause from an observed effect (Peirce, 1868). Researchers used abductive thinking, often in conjunction with analogical reasoning, to develop hypothetical explanations of the results they were seeing. Sometimes these hypotheses could be tested immediately; in other cases months or years were needed to accumulate necessary evidence to support the hypothesis.

With his epidemiological profile, Curran used abduction to consider what might generate this pattern. Without dismissing the drugs as a possible cause (node 395), Curran was leaning toward a sexually transmitted infectious agent as the source of disease (node 396). He believed that since the most striking characteristic of the patient population was its sexual behavior and since it was the only characteristic common to all patients it was the most likely solution. This belief was supported by an analogy to Hepatitis B, which had a similar pattern of transmission. To support this hypothesis, Curran's team conducted a cluster analysis (node 397) linking known cases via sexual contact and found a high level of sexual connectedness amongst the first cases. "Nine of the first 13 cases, whether living or dead, were linked to each other through sexual contact. Eventually they linked up to 90 other people around the country through sexual contact, which was 40 percent of the first 220 gay men reported with AIDS." The cluster analysis supported the sexual transmission hypothesis.

Over the next two years data from new cases accrued. Three other risk groups came to Curran's attention: recent Haitian immigrants, hemophiliacs, and intravenous drug users. The Haitians could be incorporated into the sexual transmission explanation, since several of the patients had had sexual encounters in Haiti. The latter two groups suggested that blood born transmission was also possible. This increased the parallelism between AIDS and Hepatitis B, which is also transmitted by blood and sex. Curran became even more convinced that the source of AIDS was an infectious agent similar to Hepatitis. This is illustrated in the connections between nodes 394, 419, and 396. At this point, Curran was completely convinced that AIDS was transmitted in a way that was analogous to Hepatitis B and his efforts turned towards convincing others he was correct and implementing policies to limit transmission.

As a clinician, Waldmann found it easy to identify the opportunistic diseases in the first NIH AIDS patient. The question was what underlying diagnosis would make sense of this pattern of infection. In this respect AIDS was not unique: "Even in that era before AIDS, one recognized this pattern of infections as the hallmark of a cell-mediated immune defect. If a patient didn't make antibody, we knew he would have trouble with highly pathogenic bacterial diseases." This explanation is illustrated in the abductive connection between node 383 and node 384. If this hypothesis was correct, the patient's body should not respond to known pathogens. Waldmann's team tested the cell-mediated immunodeficiency hypothesis by looking at the patient's response to skin tests for diseases to which he had been exposed and cultures testing his immunoglobin production (node 386). These tests confirmed the belief that the cause was a cell-mediated immune deficiency.

Fauci's immunology lab had previously studied B-cell hyperactivity, so that aspect of the immunological profile intrigued him. His group undertook a controlled investigation of B-cell involvement with the disorder and found clear evidence of polyclonal B-cell activation, which they suggested might best be explained by a virus. "These findings of polyclonal B-cell activation in vivo are very suggestive of viral stimulation or transformation." (Lane, et al., 1983). The failed transplant procedure also led to an important discovery. The destruction of the transplanted cells suggested that the underlying agent was destroying the environment of the immune system and was transmissible to the new tissue. These two insights led to the critical understanding that a virus that was destroying the immune environment itself (node 416).

Discovering the Virus: The Deductive Phase

Each of the researchers produced an insight into the disease that was the culmination of their work and led others to have new ideas about AIDS. Curran's insights that the disease was infectious and transmitted via blood or sex and Waldmann's insight that his patient's many infections indicated a cell-mediated immunodeficiency led to Fauci's work. These insights convinced him that AIDS was going to spread and become a major problem that he could help resolve. All three researchers helped contribute information that lead to the ultimate discovery of the HIV virus.

Like Fauci, Gallo was not immediately intrigued by AIDS. He only became involved when the disease seemed to intersect his own specialty, human retroviruses. In fact, Curran recalls dedicating one of his earliest talks presenting information about AIDS to Gallo and trying to elicit his interest in the problem. "So I got up and I dedicated my talk to him. I said, 'Since you have worked on T4-trophic viruses, what you need to do is find this one.' … He listened, and that is probably why he occasionally attributes his involvement in AIDS to me." Ultimately, in his interview, Gallo lists seven things that convinced him that AIDS was caused by HIV. Some of this evidence is technical, based on laboratory data and techniques. But also included are: the epidemiological profile and modes of transmission, the fact that the disease was characterized by immune deficiency combined with knowledge that in cats a retrovirus was known to cause immune deficiency, and the immunological results that suggested a virus causing specific defects relating to CD4+ cell. The conclusions of the other researchers can be seen feeding into Gallo's work in the connections between nodes 396, 384, 416, and 417.

Discussion

This paper describes how scientists engaged with a novel problem, learned about it and developed the insights necessary to lead to a solution. We found that researchers went though several stages in their discovery processes. First, researchers had to take ownership of the problem. Second, they gathered data and used inductive processes to profile the problem to be solved. Third, they used abduction and analogy to generate explanations for the profiles they observed and tested these explanations. And finally, they generated conclusions that were picked up by other scientists and influenced future work.

While parts of the discovery processes observed have received research attention (i.e. hypothesis testing), three major aspects described have not been generally discussed. First, in most studies the decision to take ownership of a problem is not addressed, possibly because in laboratory paradigms the experimenter provides the problem. For AIDS, this initial step was very important; problem ownership required the researcher perceive the problem as significant and within his purview. Future research should further explore these two requirements and be alert to additional factors that may influence this initial stage.

Second, abduction was found to be an important part of the discovery process. After making initial observations, researchers engaged in abduction to generate hypothetical causal mechanisms. This study suggests the importance of futher research on how people engage in abduction and when this type of reasoning is used. As a diagnostic problem, AIDS may have required more abductive reasoning than other domains, but it seems likely that abduction will have some role in many areas.

Finally, research on scientific reasoning usually focuses on individual scientists. This work suggests that the social dynamics and interchange of ideas among researchers have an important impact on the discovery process. These social aspects of discovery are probably common to many discovery processes but are particularly evident in this case because of the urgency of the problem and the nature of the data set. Because AIDS was completely unknown and required an immediate solution researchers had to share work immediately. While in other discoveries researchers might have influenced each other via publications and presentations across years or decades, in this case the social influences were more immediate and direct. Also, in most cases, discoveries are seen as the work of a single individual whose papers and biography are studied; little is known about others working on the problem. In this case, because interviews were conducted with multiple individuals, many view points are available to see the interchange of ideas. Finally, AIDS research received more public attention than most research. This meant that in addition to considering input from other scientists, the researchers had to consider how their decisions and conclusions would be evaluated by policy makers and the public at large. Future research tracking the social interactions amongst scientists and between scientists and other stakeholders could help understand these diffuse cognitive processes.

Conclusions

We think of science as conducted by isolated individuals, removed from the world in ivory towers functioning within the confines of narrow disciplines. And, although interdisciplinary work is increasing, this is still often true. Scientific disciplines tend to define themselves in terms of fixed methods and topics (Livingston, 1987). The case of AIDS shows that science does not have to work this way. Here a real world problem demanded a scientific response and researchers rose to the challenge. Each used the unique methods of his discipline and gained valuable insights. But they also collaborated and the ultimate solution depended on efforts distributed across disciplines. This study points to the importance of these social factors in scientific cognition. But beyond that, it suggests the need to provide ongoing support mechanisms for interdisciplinary collaboration and dialogue.

Acknowledgments

We are indebted to Victoria Harden the historian at the NIH whose interviews were used as a primary data source, to Helen Altman Klein for suggesting AIDS as a domain, and to Ashley J. Wenner for helping with coding.

References

Atlas.ti: The knowledge workbench (Version 5.2.8). (2008). Berlin: Atlas.ti Scientific Software Development.

Banxia decision explorer (Version 3.3). (2005). Kendal, UK: Banxia Software.

Bohm, A. (2004). Theoretical coding: text analysis in grounded theory. In Flick, U., von Kardorff, E., & Steinke, I. (Eds.) *A Companion to Qualitative Research*. (pp.270-275). London: Sage.

Clancey, W.J. (1985). *Heuristic classification in artificial intelligence*. North-Holland: Elsevier.

Elstein, A.S. & Schwarz, A. (2002). Evidence base of clinical diagnosis: Clinical problem solving and diagnostic decision making: selective review of cognitive literature. *British Medical Journal, 324*, 729-732.

Fauci, A.S. (1982). The syndrome of Kaposi's sarcoma and opportunistic infections: An epidemiologically restricted disorder of immunoregulation. *Annals of Internal Medicine, 96,* 777-779.

Gottlieb, M.S., Schanker, H.M., Fan, P.T., Saxon, A., Weisman, J.D., Pozalski, I. (1981). Pneumocystis Pneumonia – Los Angeles. *Morbidity & Mortality Weekly Report, 30,* 1-3.

Klahr, D. & Simon, H.A. (1999). Studies of scientific discovery: Complementary approaches and convergent findings. *Psychological Bulletin, 125*, 524-543.

Lane, C., Masur, H., Lynn, E., Whalen, G., Rook, A., & Fauci, A. (1983). Abnormalities of B-cell activation and immunoregulation in patients with the acquired immunodeficiency syndrome. *New England Journal of Medicine, 309*, 453-458.

National Institutes of Health. (n.d.). *In their own words: NIH researchers recall the early years of AIDS*. Retrieved February 1, 2007, from http://aidshistory.nih.gov/transcripts/index.html

Nersessian, N.J. (1992). How do scientists think? Capturing the dynamics of conceptual change in science. In R.N. Giere (Ed.), *Minnesota studies in the philosophy of science: Vol. 15. Cognitive models of science* (pp. 3-42). Minneapolis: University of Minnesota Press.

Peirce, C.S. (1868). Some consequences of four incapacities claimed for man. *Journal of* Speculative Philosophy, 2, 140-157.

Popper, K.R. (1959). *Logic of scientific discovery*. London: Hutchinson.

Shalin, V.L. & Bertram, D.A. (1996). Functions of expertise in a medical intensive care unit. *Journal of Experimental and Theoretical Artificial Intelligence, 8*, 209-227.