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# AN APPROACH FOR RELATING SOCIAL STRUCTURE TO COGNITIVE STRUCTURE

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It is proposed that the decision making process is intrinsically formulative in nature; i.e., for the individual the crux of the process is in the development of a frame, a knowledge base, that can be used to make the decision, rather than the evaluation of the alternatives '*per se*'. A two stage model of decision making is forwarded. In the first stage the individual develops his frame. This is the critical, formulative, stage and dependent on the socio-cultural environment. In the second stage the individual makes a decision by evaluating his frame. This stage is mechanical, evaluative, and determined by the frame formulated during the first stage. A consequence of the basic thesis is that the social and cognitive processes can not be decoupled if we are to understand decision making behavior. However, there are few methods currently available that allow the researcher to look at the relationship between the social and the cognitive process.

Herein, a set of methods that permit the researcher to look at this relationship are described and then applied to a particular case study. On the social side these methods are based on a network representation of social structure. On the cognitive side these methods are based on a set of semantic models of human knowledge. A set of cognitive models for representing information are presented -- these include frames, maps, and knowledge bases. A set of programs, *Frame Technology*, for coding, manipulating, and analyzing frames, based on these models, are briefly described. The relationship between social structure and individual cognitive formulations for a group of undergraduates at MIT formulating the problem of selecting a new tutor is then examined using these programs.

This work is an overview of a new approach to studying decision making, one that tries to relate social structure to cognitive structure at an empirical level. It is not a detailed analysis of a particular decision: the point is not what decision was made, but the role that information played in this decision. Nor is a detailed discussion of the set of new methods provided: the point is not how the methods work, but the way in which they can be used.

## INTRODUCTION

MIT, or the *tool and die factory of Cambridge* as some of the students have affectionately(?) called it, like most colleges and universities has many living groups — fraternities, dormitories, etc. To an outside observer Third East appears as just an ordinary section of a typical dorm (East Campus)* at MIT. East Campus consists of two parallel block long five story buildings. Third East is simply the third floor of the east parallel — a block long hall where a group of undergraduates, both male and female, freshmen to senior, live. However, to those in the know, 3E, at least at the time of this study, is a very unique living group. To begin with, the hall has a campus wide reputation for parties, sports participation, and hacking in general.† Each year the hall sported teams in most of the intramural events — football, ice hockey, basketball, badminton, volleyball, bowling, soccer, softball, and even chess. And of course there were of those less officially organized activities like throwing pumpkins off the 30 story green building after the halloween party, or installing a fake exhibit (a plastic aircraft carrier complete with specially aged plaque of activities) into the MIT Hart nautical museum after midnight — where it went unnoticed by the administration for close to three moths.‡ All of this activity is rather amazing given that there are only around 42 to 45 students living on 3E at any one time, and that this is MIT — one of the few halls of higher learning where the Deans actually tell the tutors to "get the students to *stop* studying".

Unlike many MIT living groups there is a high degree of interaction among the students on Third East. They study together, and they hack together. This has led to the development of an internal micro culture among the members of the hall that is bridled with traditions — like freshmen shower night, pancake feeds, killer frisbee, . . . — and

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* The official name for this dormitory is Alumni House; however, it is referred to by its inhabitants as East Campus.

† Hacking is an MIT word that stands for, well, doing anything intensely, doing something with gusto, and doing anything but studying mandatory course work. Hacks are jokes or pranks, like hanging a shopping cart from the top of a crane or building a wishing well in someones room. To hack could be anything from working on a hack, to sitting around talking or playing cards, to working on a special project that is of great interest to you (like building your own home computer or stereo). Hacking ones-self would be spending a great deal of time doing something of special interest at the risk of not spending enough time on what one is ostensibly required to do.

‡ This model, the USS Tetazoo, now resides in the MIT archives as part of the collection on hacking.

steeped in legends — like deBronkhart who literally flamed when he opened his mouth, Gwhite and Roberts who blew up the coolie closets every weekend, *I hit trucks scmeltz*, mountain man Dan who repelled between the parallels, m2p and his midnight tours, . . . This social lore is transmitted from one generation of Third Easters to another through the process of individual communication.

I was a member of this living group for 7 years. For the first four years I was simply another undergraduate on the hall. During the last three of these years, my husband and I were the graduate residents, or tutors, on 3E. In February of 1981 we called a hall meeting and told the students that we would be gone the following year. An uproar broke out, and the tutor selection process on 3E started. During the ensuing 2 and a half months the students did not behave in a classical decision making fashion — they did not set out the alternatives that were available, evaluate the consequences, choose the alternative with the highest utility, and so on. Rather, they began by determining (a) what information they had, (b) what information they needed, and (c) how they were going to get it. The students went through an intricate information gathering process with relative ease, one where the information they gathered actually affected not only the way they thought about the decision but what alternatives were available.

Choosing a new tutor was a relatively new social decision to these students; i.e., only one class, the seniors, had ever been through the process before. And the rest of the undergraduates weren't sure that the seniors opinions should count, as they weren't going to have to live with the new tutor. The oral history of the hall, the accepted social norms, legends about past tutors, and the internal social structure all became important factors in the decision by modulating the students information gathering process; e.g., by affecting what information they chose to gather and where they chose to gather it from.

In classical decision theory a crucial underlying assumption is that there is complete information. This leads to a situation where all of the alternatives are available for analysis, and the analysis becomes the critical step. Since the analysis is a purely mechanical process, the best decision maker becomes the machine — the computer who will not make any mechanical errors. In a real world situation where information is not only incomplete, but can even be fuzzy (e.g., having a probabilistic interpretation, or multiple interpretations), the analysis of alternatives appears as a relatively trivial aspect. In artificial intelligence (AI) the analysis of a plethora of protocols from a variety of situations suggests that the ability to make a particular decision hinges on the ability to handle a large number of task specific pieces of information (Newell, 1972). These facts, and my experiences on Third East and with other decision groups have motivated the conclusion that the crux of the decision making process lies in the formulation of the decision, in the establishment of which facts are important and the interrelationships between these facts.*

In the following pages, the relationship between individual cognitive structure and general social structures during the decision making process is discussed. The emphasis of this presentation is on the interrelationship between social and cognitive structure; not the decision process as such nor the decision outcome. The proposed theory and methodology is grounded by tying it to the study of a particular social group (Third East) and the decision process in which the members of the group are involved (tutor selection). The Third East tutor selection is not studied for itself, but as a vehicle for exploring the nature of social decision making, the relation of social to cognitive structures, and as a test data set for applying the newly developed methods. The exact voting algorithm, who voted for whom, who was finally chosen, and so on are irrelevant to the study. What is relevant is the relationship between the students social structure and the way in which they formulate their needs, their desires, for what they wanted in a tutor.

They are three main parts to this discussion: (1) process formulation (*section 1*), (2) method overview (*section 2*), and (3) case evaluation (*section 4*). In the following section (1), a general two stage model of individual decision making is presented that combines both an ability to handle large quantities of task specific information and an ability to mechanically evaluate alternatives. This decision making process is hinged on the interplay between individual cognitive structures and the general social structure. Interaction and hence information flow is seen as the driving force behind this interplay and hence the development of individual and social structures. Section 1 is a brief overview of a top level model of the decision making process. This process is at times, imprecise. In later sections, underlying models of information and cognitive structure are presented. These models admit a more precise description of the decision making process which will be presented as it becomes relevant; although, for the most part, such a description is beyond the scope of the current paper.† Section 2, *Frame Technology*,

* Researchers in the decision theory tradition have recognized the importance of problem formulation on problem solution (Hogarth R, 1984, 1984, Tversky, 1980).

† For a more detailed description of the model the reader is referred to (Carley, 1985a) and (Carley, 1984).

contains a presentation of the underlying models used for representing information and thus cognitive structures. Following this is a brief exposition on a set of methods based on these models (*Frame Technology*), that I developed for coding, analyzing, comparing, and combining decision formulations (*frames*). These methods/programs allow one to study the interrelationships between cognitive and social structures. Following this is an interlude on the role of interaction, section 3. And finally, in section 4, some of the uses to which these methods can be put are illustrated via an examination of the relationship between the social structure on Third East and the student's formulation of the tutorship job. I want to stress, that I am trying to provide a basic overview and description of a new way of approaching the study of decision making; therefore, many technical details will be left out entirely and others will only briefly be mentioned.*

## 1. FORMULATIVE DECISION MAKING

I propose that, for the individual, the decision making process is intrinsically formulative in nature. The crux of the process is in the development of a *frame*, a knowledge base, that can be used to make the decision; rather than the actual evaluation of alternatives, which is seen as a very mechanical and relatively trivial part of the process. Viewed in this way, decision making can be modeled as a two stage process where the first stage is formulative and the second is evaluative. However, the evaluation is dependent on the formulation; i.e., in the second stage the frame formulated in the first stage is evaluated.

### 1.1. The Basic Process

What is it, that individuals do when they find out that they have to make a decision? If you listen to people make decisions, it appears that they do not start with a blank slate, an empty frame. Rather, they start out with a set of ideas about the thing to be decided upon, an *initial frame* composed of what information is available, what information is needed, how to get that information, and so on. This initial frame is then used as a basis for a new, more developed frame, and it is used to direct the gathering of new information — see diagram 1. This

*For more details the reader is referred to (Carley, 1984).

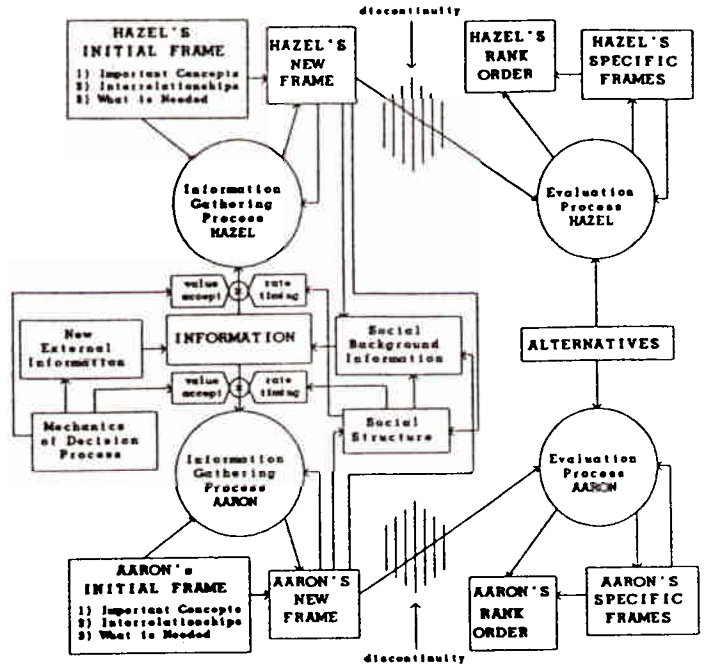


DIAGRAM 1 The decision making process

This diagram portrays the decision making process for two individuals (one at the top and the other at the bottom) as they simultaneously go through the process of formulating a decision frame and then evaluating a set of alternatives on the basis of this frame. Note that the social background information, the social structure, the set of new external information, and the mechanics of the particular decision are the same for both individuals. However, because the individuals have different initial frames (cognitive structures) and occupy different positions in society they may actually evaluate the same information differently, choose to accept different information, and receive the same information at different times and at different rates.

Individual decision making is modeled as a two stage process consisting of a formulative and an evaluative stage. The formulative stage (left hand side) centers around gathering information, and formulating the decision. Each individual at the cognitive level, separately gathers and processes information. Some of this information may be gathered from members of the group while discussing the decision, it may be gathered from members outside of the group, or it may be discovered by independent invention. As members of the same group, working on the same decision problem, the individuals can potentially access the same set of information, both directly from the task and indirectly from the social environment. A discontinuity, for example the need to take a vote, forces individuals to move from the formulative to the evaluative stage. The evaluative stage (right hand side) centers around mechanically evaluating alternatives on the basis of the pre-constructed formulation. Each individual at the cognitive level, separately evaluates the decision; i.e., they weight the alternatives and make a choice. All individuals rely on the same set of alternatives, when the decision being made is a social one.

recursive process of *frame-development information-gathering frame-development* continues until the individual is forced to make a decision.

The movement from the information gathering process to the evaluative process is an abrupt transition, forced perhaps by outside forces (e.g., the Deans have to know by a certain date whom the students want as a tutor). This abrupt transition is viewed as a product of a discontinuity in the normal cycle — the *frame-development information-gathering* cycle. During the evaluation stage, the individual uses the most recently developed formulation of the problem, the most recently developed frame to evaluate the ostensible alternatives — those choices that are being considered.* This evaluation is a very mechanical process basically amounting to seeing how well each alternative fits the current frame. One result of this fitting procedure is a specialized frame for each alternative — a detailed description of that alternative *vis-a-vis* the decision to be made. These specialized frames can be used during the evaluation stage to compare alternatives, such that a ranking of alternatives can result. If we know how the individual formulates the problem and if we know the set of alternatives, we can always reproduce his choice.

### 1.2. Information Gathering

The formulation of the decision by an individual is a dynamic result of the information gathering process. During the formulative stage, a plethora of information is available. Some of this information is new to the social unit; e.g., it could be dependent on the particular decision to be made as in the case of hiring someone for a job, who applies affects what information those doing the hiring have. And, some of this information is general *social background information* — that information which everyone knows; e.g., you bring a present to a birthday party. Further, the mechanics of the imposed process for a particular decision† and the social structure are special pieces of information that

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* Note, the set of alternatives may change over time. In the case of a formal social decision, like tutor selection, the set of alternatives are often fixed or limited at the time the final decision is being made.

† Note, a distinction is being made here between the process that an individual goes through in making a decision, any decision, and the process defined for a particular decision. The first of these is referred to as the *decision making process* and the second of these as *the imposed decision process*. The first is comprised of the behavior that an individual exhibits in coming to a decision; i.e., the process of frame formulation and evaluation. The second is comprised of those regulations on, and time frame of, a particular decision; e.g., the rules of selecting a tutor imposed by the deans, and the time by which they needed a solution.

actually serve to modulate what information is available, the rate at which it becomes available, when it becomes available, whether or not the individual accepts that information (incorporates it into his cognitive structure), and even the way the individual values that information. The mechanics of the imposed process for a particular decision are in themselves new information, and the social structure is part of the social background information. The evolution of the individual's frame during the formulative stage of the decision making process is thus modulated by the social structure and the mechanics of the imposed decision process. Social background information and the social structure change as individuals change their perceptions of the world, as they formulate new frames. Whereas the mechanics of the imposed decision process, what has to be done when, etc. is for many social decisions a process that is, at least in the short run, exogenous. These mechanics are often set prior to the beginning of the imposed decision making process and often by outside groups.

However, as the individual's frame evolves it affects the individual's position in the social network and social background information. That is, we expect the individual's social position to alter as he alters his opinions, beliefs, interests, etc., as he alters the way in which he thinks about the decision(s) to be made. Further, as the individual's frame evolves, as he learns new information it is expected that social background information (that information that 'every one' knows) to change; e.g., as more people accept a particular 'fact' it becomes a piece of social knowledge.

### 1.3. Societal Impact

The process roughly outlined is true not just for one individual, but for all of the individuals in the social unit. All individuals are simultaneously going through the decision making process, gathering information from the same base, and being affected by the same social environment and strictures of the particular decision being made. However, different individuals have different social positions in the social structure and therefore will be gathering effectively different information due to the fact that social structure modulates the transfer of information. Social structure serves to limit who has access to what information by restricting interaction patterns.

All individuals are assumed to have access to the same information; however, what information they actually access, when they access it, how they value that information, and whether or not they even accept that information, is affected by both the mechanics of the decision process, and the individual's position in the social network. As information is gathered, the individual's frame evolves resulting in changes in the way in which the individual defines various concepts. This new frame, in turn, facilitates future communication, and alters the pattern of interaction. As all of the individuals' frames co-evolve social background information evolves: social and cognitive structures recursively evolve.

Cognitive development across the members of the social unit leads to the development of the social knowledge base; i.e., as the individuals' frames co-evolve social knowledge evolves. Co-evolution of the individuals frames also leads to a repositioning of the individuals relative to each other, to alterations in the extant social network. Consequently, the social structure changes. Further, the social knowledge base — that collection of facts which everyone knows — can be thought of as a standardized system of implicit signals and coding rules, an articulation of the social culture. As Cicourel notes, without such a base "everyday interaction would be impossible for nothing could pass as 'known' or 'obvious', and all dialogue would become an infinite regress of doubts".*

### 1.4. Comments

Diagram 1 is a pictorial presentation of the process that individual's go through to make decisions, to solve problems. There are three main points here:

- The critical stage of the decision making process is the formulative stage.
- The social structure and individual cognitive structures develop recursively.
- During the decision making process the social, cognitive, and evaluative structures are coupled; i.e., their determinations are interdependent.

## 2. FRAME TECHNOLOGY

*Frame Technology* is a set of tools that collectively allows the researcher to code and analyze verbal data using a network approach. First, the

*(Cicourel, 1974, p. 86).

underlying models will be described. And then, the tools based on these models will be discussed.

## 2.1. Model

When decision making is viewed as a primarily formulative process, the ability of the individual to make a decision, and the process by which this is done, hinges on the utilization of information. Therefore, modelling information becomes a prerequisite to the study of decision making as it relates to the interrelationship between social and cognitive structures. Further, given a model of information it becomes possible to develop a model of the way in which the individual formulates the decision, his frame. This frame is that aspect of the individual's cognitive structure that relates to the division at hand.

*2.1.1. Underlying Models* Information is viewed as relational entity composed of a set of discrete pieces. A piece of information, is viewed as a fact. Minsky* suggest that "a fact is a relationship together with a few things the relationship ties together in a meaningful way." A fact is the simplest articulatable structure. Herein, in order to operationalize the Minskian notion, a fact is modeled as two concepts† and the relationship‡ between them.§ See diagram 2. Some examples of facts are *Jay loves Ann, Gnerds aren't friendly*, and *Someone who fits in with the hall won't insist on quietness.*

We could talk of there being a *set* of facts. I will refer to a collection of facts as a *knowledge base*; e.g., the social knowledge base is that collection of facts such that the majority of individuals in the society

*(Minsky, 1975, p. 181).

† A concept can be a single word, e.g., *tutor*, or a set of words that describe an idea or object, e.g., *fits in with the hall*. These words can be specific, e.g., *Jay*, or general, e.g., *friend*. Thus, concepts can serve as either place holders or specific nodes that fill these general place holders.

‡ A relationship is a link between two concepts. Like a concept, a relationship is a single word, e.g., *has*, or a set of words that describe a relationship, e.g., *is not a*. Before continuing, I'd like to point out that it is often the case that the relationship between concepts (the tie) is directed; thus, creating a one way link. In this article, all ties are implicitly treated as bi-directional. The reason for this is simply so that the discussion of creating and using frames can proceed without getting bogged down with the technical details necessary when one allows uni-directional ties. Similarly, a discussion of other features of these ties, e.g., strength and meaning, is also beyond the scope of this presentation.

§ For a more detailed description of the way in which these models are operationalized the reader is referred to (Carley, 1985b) and (Carley, 1984).

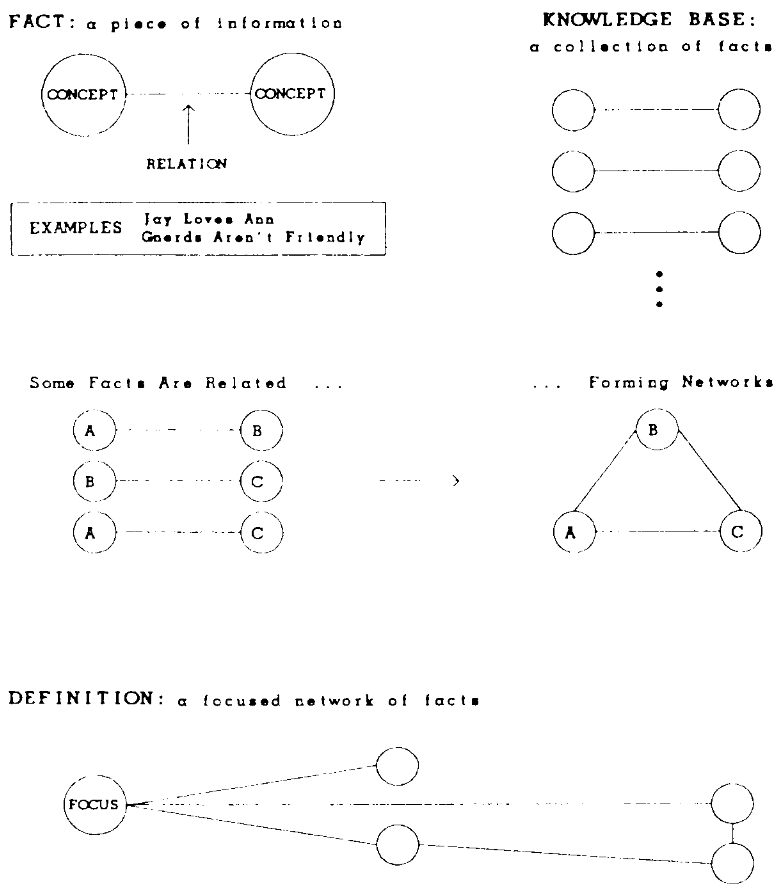


DIAGRAM 2 Underlying models
The primary model out of which all others are built is the model of a fact as two concepts and the annotated relation between them. Concepts are represented by nodes (circles). And the relationship between concepts are represented by the lines or ties between these nodes. A solid line indicates that the relationship is positive, a dashed line indicates that the relationship is negative. The darker/thicker the line the stronger the relationship.

"know" or "accept" that fact. Within a set of facts we expect that some of the facts will interrelate by sharing concepts; e.g., Jay loves Ann, Ann loves Greg, and Jay and Greg hate each other. The relationships between facts results in the formulation of networks, some of which are semantic networks.* It may be that all of the facts in a particular knowledge base are connected; however, this is not necessary. In other words, a knowledge base may contain networks and yet not be one.

Some networks are more interesting, or have special interpretations; e.g., the definition. A definition is a focused network of facts such that the focus is the concept being defined and the other concepts in the network serve to define the focus by their relationship to it and each other. Underlying this notion of definition is the notion of *relative definition*; i.e.,

- Concepts are meaningless in isolation and can only be defined by their relationship to other concepts.

In terms of social usage, general communication, there are no absolute definitions only relative ones — we do not go to the dictionary to understand a word, but understand it through the context in which it is being used. A social definition for a particular concept would be a network of facts focused on that concept such that each of the facts is accepted by the majority of individuals in that social unit.

*2.1.2. Structural Models* Basically, any data collected can be represented as a set of facts, a knowledge base. From the standpoint of

* The notion that the organization of concepts in memory can be represented as a network is not new. There have been many diffferent formulations: e.g., schemes (Anderson J, 1973, Bobrow, 1976), frames (Minsky, 1975), transition networks (Collins, 1975, Clark, 1977, Wyer, 1979), semantic nets (Simmons, 1973, Schank, 1973), and scripts (Abelson, 1969, Abelson, 1976, Schank, 1977). Common to all of these conceptions is the notion that the representation of knowledge in memory is in terms of ideational kernels or chunks that are interconnected. The types of interconnections, whether or not they are static or transitional, the level of generality or specificity of the kernels of knowledge, and so on differ across conceptions as do the rules for connecting networks.

The difference in the proposed representation schemes is not so much in the technique as in the focus. In general, researchers who use scripts (Abelson, 1976, Schank, 1977), and schemata (Rumelhart, 1976, Tesser, 1977, Tversky, 1980), tend to focus on the dynamics of action; whereas, those who use frames (Charniak, 1972, Minsky, 1975, Collins, 1978) tend to focus on concept representation, meaning, and description. In this paper, the focus is on concept representation; i.e., on representing the way in which an individual thinks about or defines a concept relative to other concepts in his vocabulary. Since the focus is concept representation, the current work follows most directly from the ideas suggested by Minsky, Collins, and Gentner. At one level, the representation scheme presented herein can be thought of as an operationalization of Minskian frames. At another level, the scheme presented is just a general model for representing articulatable information regardless of the source of that information or its current storage location that can be mapped onto most of the other network based schemes.

making a particular decision, the knowledge base is little more than a reference base. The decision maker does not utilize all of the information at his disposal. Rather, he utilizes a special subset of that information, a subset that is constrained by the decision topic, the context in which the debate is set, and so on. I further suggest that the decision maker does not simply evaluate a list of facts; rather, he makes his decision on the basis of the perceived structure of facts, the interrelationships between facts. In other words, the decision is based on a structure composed of the facts that are germane to that decision, and the structure itself aids the decision maker in coming to a decision. A *frame* is a representation of such a structure. A *map* is, a similar, albeit simpler, representation. Refer to diagram 3.

A frame, as proposed by Marvin Minsky is a data structure for representing situations or objects as a hierarchical network of nodes and relations such that the top levels are always true and the lower levels can be filled with specific instances.* Frames can be thought of as a focused network of definitions where the focus is the concept of concern to the individual.† In a decision making situation, the focal concept is the item being decided. Unlike the definitions previously discussed frames are complex and contain within them multiple definitions, including definitions by example.

Frames are a powerful metaphor for describing and thinking about data. In terms of making a decision, frames can be used by the decision maker not only as a reference but as a way of structuring the way he thinks about the decision. From a research perspective, frames are a little difficult to deal with due to the multiple levels of complexity (e.g., the intermingling of the specific and the general) and their immensity (frames are large as they contain all of the information that has any relation to the decision at all). For example, a frame for the concept *tutor* would include information on the specific stages of the particular decision process, information about particular tutor applicants, information on the behavior of past tutors, a general description of what was wanted in a tutor, and so on.

A frame like structure that is less complex, but still provides structuring for the data is a *map*. A map, like a definition is a focused network of facts. Like a frame, the focus is a particular concept. Again,

* The frames discussed here differ from those discussed by authors like Goffman in that they are a representation of the inter-relationship between concepts in memory, not the dramaturgical sequential unfolding of events that define the context in which the person is acting.

† For more details refer to (Carley, 1985b).

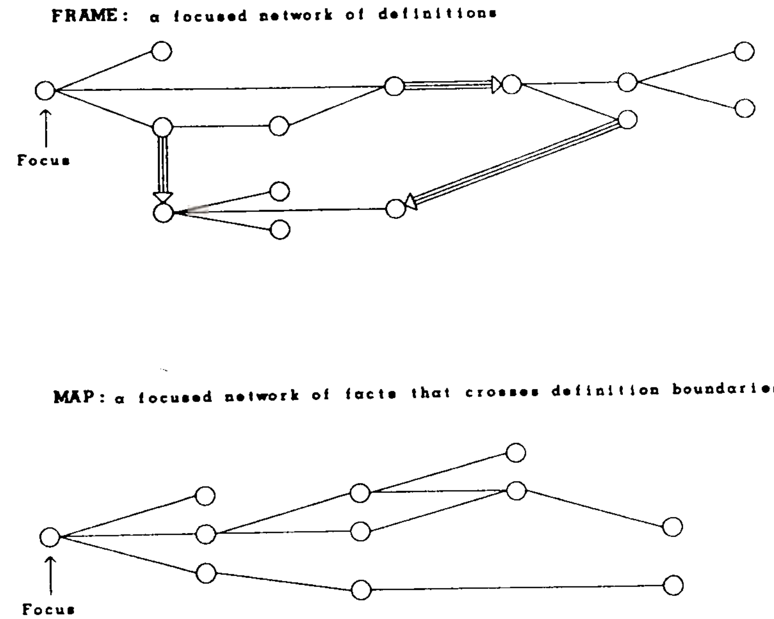


DIAGRAM 3 Structural models
The basic structural models are the frame and the map. Frames and maps are representations, or models, of an individual's cognitive structure. Both are focused on a particular concept. The frame (top) contains everything known about that concept, the map (bottom) is a sample of this frame and contains only part of what is known about that concept. A frame, as proposed by Minsky is a data structure for representing situations or objects as a hierarchical network of nodes and relations such that the top levels are always true and the lower levels can be filled by specific instances. Frames can be thought of as a set of interlocked definitions such that the definitions themselves can cross levels of complexity. Here, each level of complexity is represented as a separate structure, nodes connected by solid lines, and definitions which cross levels of complexity and thus serve to bind these sub-structures together are shown as facts with the enlarged arrows between them. The map can be thought of as a slice of a frame at a particular level of complexity. The map, like the frame or definition is a focused network of facts. Like a frame a map may include several definitions. Unlike a frame, a map because it is drawn at a particular level of complexity may actually cut across definition boundaries and hence include only part of some definitions. If the focal concept is the decision point and the level of complexity chosen is one of the general level description then the map serves as a working definition of the decision point.

in a decision making context the focus is the decision point — the thing to be decided upon, the concept to be evaluated. A map can be thought of as a slice of a frame at a particular level of complexity as defined by the aspect of the focal concept on which the map is centered. In the decision making context, one possible map is the general level description of the decision point; e.g., in the case of tutor selection this would be a general description of what was wanted in a tutor.

For a decision point, a map that represents the general level description can be thought of as a working definition of thing to be decided upon. Such a map defines the decision point in terms of what factors are important to making that decision and it contains information on what information is needed to make the decision, to evaluate the alternatives. In this article, only maps will be presented, not full frames. Moreover, all of the maps presented are of this type, general level descriptions of the concept *tutor*. Some of the maps are individual maps and represent a single student's general description of what was wanted in a tutor. Other maps are group maps and represent the description of what was wanted in a tutor what is shared by a set of students.

Referring ahead, diagrams 7, 8, 9, and 10 are examples of a maps. The first two maps represent two different groups' perception of what it means to be a tutor on Third East. These are joint maps, that is, they contain the set of facts that are shared by group members. The second two maps represent two different individual's perception what it means to be a tutor on Third East. These are individual maps, that is, they contain the set of facts presented by a single individual. The leftmost node is the decision point — the concept *tutor*. It is only by convention that the decision point is placed on the left. The other nodes are concepts that the individual/individuals feels/feel are relevant to being a tutor, to deciding who should be the next tutor. The lines indicate that there is a relationship between the two concepts that it connects: a solid line indicates that there is a positive relationship, a dashed line indicates that there is a negative relationship.*

## 2.2. Application — The Tools

Using the models for information and data structures presented in the last two sub-sections a series of program were developed to code, modify, analyze, compare and combine maps. Collectively, I refer to

* In the actual programs, the relationship is allowed to vary in strength from plus three to minus three. However, for simplicity of exposition the problem of allowing the relationships to have strength is not dealt with explicitly in this article. Similarly, the relationships are allowed to be uni-directional in the programs; although, in this article all connections are treated as bi-directional, denoting merely the existence of a connection between the two concepts. Similarly, even though relationships can take on different meanings or values, in this article the concern is only with the existence of the relationship.

these programs as *Frame Technology*.* These programs are written in *C*.† They are general programs; i.e., they are not dependent on any feature of the Third East tutor selection data base. These programs along with the *UNIX*‡ operating system form the basis for a management information system for dealing with such network data.

*2.2.1. Creating Data Bases* To create the knowledge bases that were used for the following analysis, both the social knowledge base and the individual knowledge base (or in this case individual maps) a coding program was developed — CODEF. CODEF is a user oriented program that allows the coder to interactively created a knowledge base.§

To begin with, I reconstructed the social history of the hall from both the oral history and specific discussions with ex-hall members. This history goes back to the first tutor on Third East, and covers a span of almost 15 years. Using this reconstructued history and 5% of the time I interviews‖ CODEF was used to create the social knowledge base for tutorship knowledge — see diagram 4.¶ A series of 217 concepts were located as were the relationships between these concepts. Note, CODEF uses the social knowledge base as it is being constructed to aid the coder; e.g., by reminding the coder what concepts are currently available, or what connections have already been made. Once

* Note, these programs were developed by the author to handle relational/network data. For more details on these programs the reader is referred to (Carley, 1984) and (Carley, 1985b).

† *C* is a high level programming language — (Kernighan, 1978).

‡ An operating system is the top level set of commands that the computer user uses to interface with the computer. Common operating systems include TOPS-20, DOS, UNIX, and VMS. The UNIX operating system is written in C, a result of which is that it is easy to incorporate UNIX commands into C programs — (Kernighan, 1984).

§ Both frames and maps are subsets of data bases; therefore, a program that can code a knowledge base can be used to code maps and frames. Herein, it is only used to code maps.

‖ The current students on the hall at the time of the tutor selection were interviewed three times during the tutor selection process: time (1) at the beginning, immediately after the students were told that they would need to select a new tutor; time (2) during the middle of the process, after they had gone through most of the applications and had decided on some of the people to interview; and time (3) at the end, after they had voted on which of the interviewed candidates they wanted as a tutor. Each interview was with a single student. The interviews were open ended, free format, with each of the students being asked the same core set of questions.

¶ The social knowledge base contains the set of facts that as part of the oral tradition of the living group are shared by a majority of the students in the living group. For more information on the use and construction of this knowledge base refer to (Carley, 1985b) and for more information on the social knowledge base itself refer to (Carley, 1984).

constructed, the social knowledge base can be analyzed directly and it can be used to code, modify, and analyze the individual's maps. To aid in the analysis of the social knowledge base, the program GENSOC was created which locates network or social maps; e.g., GENSOC can be used to locate the social definitions of the concepts in the social knowledge base.

For each of the individual students in the study the coders were given typed transcripts of an interview and then using CODEF they coded the student's cognitive map for tutor (the student's general perception of the tutorship job). This map is a general map; i.e., it is a general statement of what that student thinks the tutorship job entails, it includes information as to what things the student wants to find out about the tutor applicants in order to make a judgement. Again, CODEF allows the coder to code the individual map (the students' map) interactively, and aids the coder using information from both the map being coded and the general social knowledge base.

Next the program ADDSOC was applied to the individual map to create a more robust map. In this process the map which contains the student's general impression of a tutor as coded by a coder who is naive of the general social situation in which the student is making the decision is in a sense checked for errors produced by not knowing the social context. ADDSOC is an inference engine for the expert system, SKI — (Carley, 1985b). It utilizes the social expert's knowledge on social background information (the social knowledge base) and the degree of consensus to social knowledge to make implicit statements explicit thus handling errors of omission.* The result is a modified individual map — a map of a student's perception of the concept tutor as coded by the naive coder and then corrected by the ADDSOC routine.

The final knowledge base creation routine is CODESF, an evaluation expert. CODESF utilizes social background information to aid the user in coding and then evaluating the specific maps. Specific maps are maps which describe how well a particular alternative fits the general conception (the general map). The modified individual maps for each student were then analyzed for rank information by CODESF. The naive coder was given the interview and the list of alternatives and told

* The point here was to move toward a situation where the coding was totally automated. Although this was not achieved, ADDSOC goes a long way in this direction as it removes many of the coder idiosyncrasies, and assures consistent interpretation of a large set of the available facts.

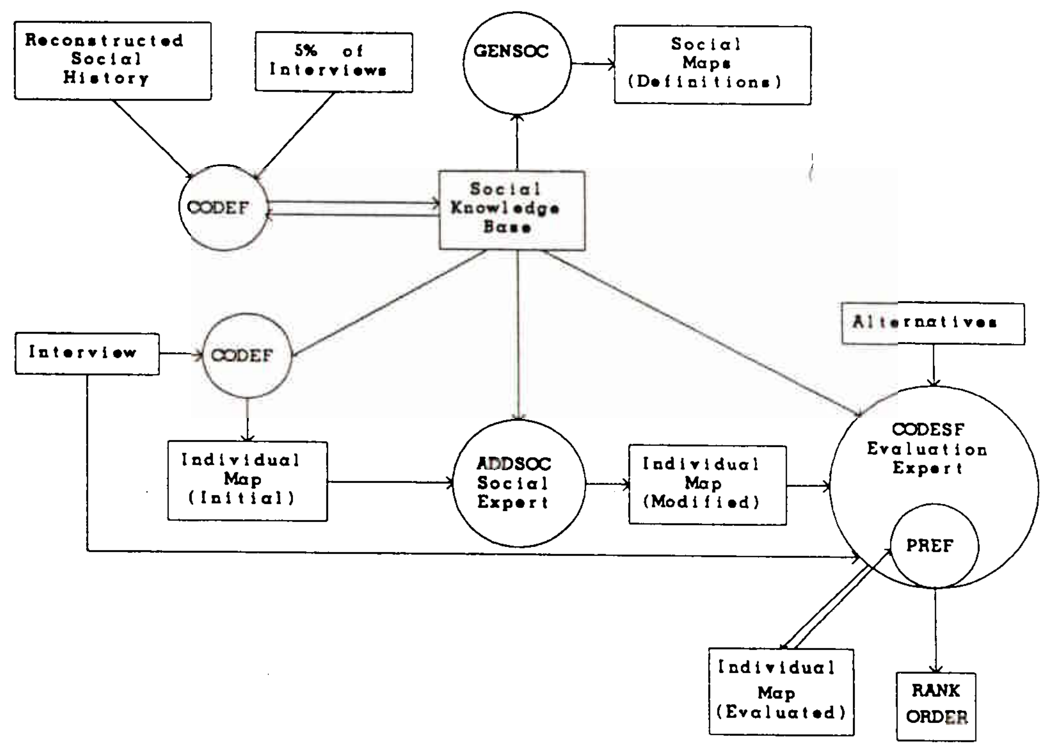


DIAGRAM 4 Inter-relationship of programs for knowledge bases
Program modules are represented by circles. Data modules are represented by squares. The lines indicate the flow of potential processing.

to use CODESF to create the specific maps. CODESF asks the coder in an interactive fashion for information on how that student (whose map is being analyzed) felt about the particular alternative (in this case tutor candidate). Once this information is gathered a ranking of the alternatives is produced. CODESF utilizes the general individual map and the social knowledge base to limit the number of questions it asks the coder. In other words, the structure of the general map is used to make the decision, to create the ranking.

*2.2.2. Meta Language for Frame Like Structures* In order to analyze the relationship between social and cognitive structures some way of combining and comparing maps is needed. That is, we can look at the relationship between social and cognitive structure by comparing what individuals know and by contrasting a single individual's perception with a shared or group perception. A series of programs were developed for just this purpose: ADDSOC, SIMDIF, JOINT, and CODESF — see diagram 5.

As previously mentioned, ADDSOC is a program for taking a particular map or knowledge base and using the social knowledge base makes the implicit facts explicit. The output is a new map, a modified version of the map originally coded from the interview. SIMDIF takes as its input two maps and produces as its output any or all of the following: the map that represents the intersection of the two maps (int); both of the symmetric difference maps (dif's); and general statistics on the difference between these maps both in terms of nodes, and in terms of connections. Similarly, JOINT takes as input two maps and produces as output the union of these maps, and general statistics on similarity. CODESF takes a general map, and with some coder assistance, creates specific maps. A sub-program within CODSEF (PREF) takes these specific maps and produces a map of ranks.*

*2.2.3. Comments* An important point here is that together, the set of programs described form the basis of a meta-language for dealing with frame like structures — refer to diagram 5. This meta-language is potentially quite powerful because there is closure over the means of combination. That is,

- the programs for combining maps produce maps as their output.

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* As an aside, the individual's frame for this decision includes, among other things, the general map, the set of specific maps for the alternatives, the map of ranks, and the relationships between all of these maps.

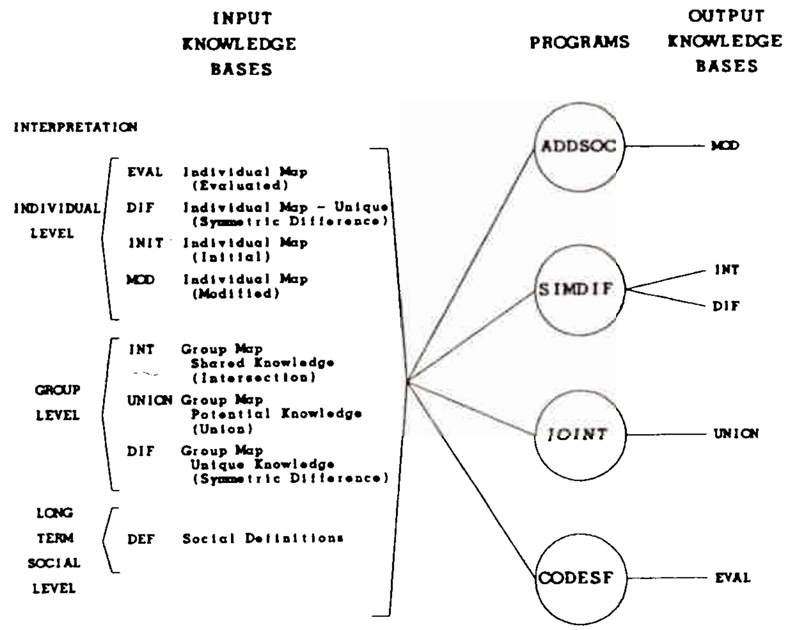


DIAGRAM 5 Meta-language for knowledge bases

The programs that comprise *frame technology* are the beginnings of a meta-language for dealing with verbal network data in a frame like manner. Part of the power of this language derives from the closure over the means of combination. That is, those programs that create and modify maps produce maps as there output; thus, admitting the potential for recursion. All of the knowledge bases (left hand side) regardless of the interpretation placed on them by the researcher have the same data format; i.e., they are all knowledge bases — collections of facts. Consequently, any routine that can accept a knowledge base can operate on any of these knowledge bases. Moreover, there are routines that can combine knowledge bases and separate out particular definitions or sub-knowledge bases from larger knowledge bases. Hence, it is possible to create group maps — shared knowledge bases — and to look at differences in two individuals' knowledge bases.

In addition to producing new knowledge bases, SIMDIF and JOINT also produce similarity and distinctiveness statistics. CODESF also produces a rank ordering. Due to space considerations, at the moment, evaluated maps are actually stored in a physically different format that is representationally equivalent.

One of the advantages to having this property, is that it allows the analyst to recursively produce group maps.

The underlying models (figure 2), and the structural models (figure 3) just presented can be used to discuss the development of the individual's cognitive structures during the information gathering process (formulative stage — figure 1). Similarly, they can also be used to discuss the evaluation of the individual's cognitive structures during the evaluation process (evaluative stage — figure 1). Moreover, the tools just mentioned (figures 4 and 5) can be used to empirically test predictions about what will occur during these stages. These tools admit the possibility of dealing with protocol data not just at the individual level but at the group level. Consequently, questions of group norms and shared perceptions can be looked at empirically at a level of detail heretofore infeasible.

## 3. INTERLUDE — THE INTERACTION CYCLE

The evaluative process is driven by the need to make a decision and/or the desire to compare alternatives. But what drives the formulative process, the recursive development of social and cognitive structures?

I want to suggest, that the driving force is simply the interaction between the individuals in the social unit. This leads to the result that:

- Cognitive development is the direct result, perhaps even a hyproduct of, social interaction.

In specific, refer here to diagram 6,* the social structure is seen as leading to individuals interacting with each other and eventually to changes in the socio-cognitive structure.†

Social structure and individual interaction are viewed as mutually reinforcing forces. One's position in the social structure (the pattern of social ties that the individual shares with other members of the social unit; e.g., sex, age, location, and job) leads to interaction. In turn, the individual's pattern of interaction is in itself a social tie and serves to produce, or at least reinforce, the social structure. For example, in diagram 6 the social unit has been divided into 4 structural groups; group A are structurally social loners who have little interaction with any one including each other, group B are structurally the social core or

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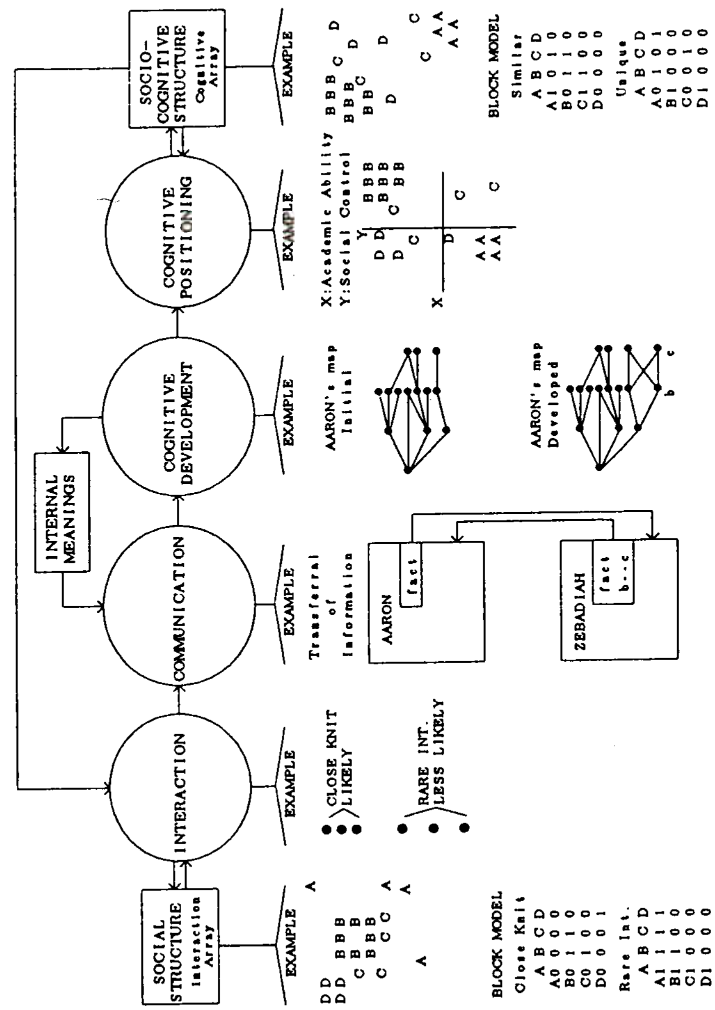
* The examples in this diagram are meant as just that, examples. The examples are based on the Third East tutor selection data set, but are not an accurate empirical representation of that data set.

† As previously stated, cognitive and social structures are seen as developing recursively. I expect that there is a time differential in this; i.e., in the short run social structures are stable and lead to the development of cognitive structures, in the long run the development of cognitive structures leads to changes in the social structure and the social knowledge base, and in the very long run to changes in the underlying social culture.


SOCIAL STRUCTURE
Interaction Array
INTERACTION
COMMUNICATION
COGNITIVE DEVELOPMENT
COGNITIVE POSITIONING
SOCIO-COGNITIVE STRUCTURE
Cognitive Array
INTERNAL MEANINGS
EXAMPLE
CLOSE KNIT LIKELY
RARE INT. LESS LIKELY
Transferral of Information
AARON
fact
ZEBADIAH
AARON's map Initial
AARON's map Developed
X:Academic Ability
Y:Social Control
BLOCK MODEL
Close Knit
Rare Int.
Similar
Unique

elite who have a high degree of interaction with themselves and with at least one member of group C; group C act as the followers or periphery for group B; and group D form a rather close knit isolated social group. Each of these groups has a unique social structured position, a unique pattern of ties; e.g., groups A and B are composed primarily of upperclassmen and groups C and D of freshman and sophomores. Structural position leads to a particular pattern of interaction on a particular issue; e.g., members of group D will interact primarily with each other, and members of group A and B will not interact across group boundaries. The closer knit the members of a group the more likely they are to interact, the less close knit the less likely they are to interact.

Interaction leads to communication, to the transmittal of information or facts from one individual to another. For example, one individual, Zebadiah, may inform another individual Aaron of a particular fact (the relationship between concepts b and c): Edith may inform Roger that the tutor candidate, Jack, likes to go out drinking to Fathers. Some of this information may be successfully communicated and hence incorporated into the other individual's cognitive structure (in this case, a map); e.g., in diagram 6 Zebadiah communicates the piece of information *b* — *c* to Aaron who incorporates it into his cognitive map by adding the two concepts *b* and *c*, the relationship between them, and other relations between existing concepts and these new

DIAGRAM 6 Interaction cycle

Across the top of this diagram a general model of the role of interaction as the dynamic process behind social and cognitive development is portrayed. Circles are used to represent cognitive and physical processes and squares to represent information or knowledge. Below each information or process block an example is provided. The social structure and the socio-cognitive structures are portrayed both in a two dimensional representation of the distance between individuals in the society (each letter represents a different individual) and in block model form. The social structure constrains the pattern of interactions. The social structure is continuously re-established through the interaction of the individuals. Interaction leads to communication which leads to cognitive development. The example for interaction shows that distance in the two dimensional representation of the social structure corresponds to different levels of interaction among the individuals. The example for communications shows that what is being communicated is a single fact from Aaron to Zebadiah and vice-versa. The example for cognitive development shows that after individual Zebadiah communicates fact *b-c* to Aaron, Aaron's map has been elaborated to include fact *b-c*. As the individual's cognitive structure evolves, the meaning that the individual attaches to particular concepts changes. This change is conceptualization serves to affect future communications and it causes the individuals to realign themselves cognitively. And the example for cognitive positioning shows that the individuals in the social unit align themselves along various lines of dissension. As individuals' cognitive structures evolve, the position of one individual to the next in terms of the way they think about things may shift. Thus shifting the socio-cognitive structure, which affects who interacts with whom; thus, altering the social structure.

ones. In this way, social interactions through the process of communication leads to cognitive development.* Further, it is expected that since the individuals are interacting with each other, communicating back and forth, that each of their cognitive structures will develop, with regard to the decision at hand their maps will change. This will lead to a situation where they have not only shared facts, but shared networks of facts; in other words, it becomes possible for them to have shared meanings, shared definitions. As these networks develop, as shared meanings evolve, the ability of the individuals to communicate is enhanced.

As the individual's cognitive structures develop they begin to reposition themselves cognitively *vis-a-vis* the other individuals in the society. With regard to the decision, as their map for a particular decision evolves individuals re-align themselves, politically. For example, on a particular issue, such as selecting a tutor candidate, there may be certain lines of dissension where the individual has a preference, and this preference may alter as the individual's cognitive map is developed. On Third East one of the lines of dissension was whether or not the student wanted the tutor to exert social control, to actually force the students to get out of their rooms and interact in certain ways. Another, was whether or not the tutor needed to have any academic ability; i.e., how important was it that the tutor actually tutor the students on the hall, actually help them understand and do their course work. Throughout the tutor selection process, as the individuals communicated more on the issue, students' maps began to develop and members of particular sub-groups came to have more similar maps *vis-a-vis* these issues. Group B basically came to prefer a tutor with both high academic ability and high social control; whereas, group A developed the stance that the academic role of the tutor was small, if not inconsequential, and that the tutor should be someone who did not interfere with the social life on the hall, did not exert social control. As these positions came to be more pronounced and increasingly communicated other individuals in the society came to accept at least one of the arguments and to align themselves relative to one of the two central groups.

As the individuals reposition themselves on various issues, their overall position in the socio-cognitive structure changes. That is, the individual's structural position in the socio-cognitive space will be altered as the pattern of cognitive ties that he shares (the facts that he

* For a more detailed description of this process refer to (Carley, 1985a).

shares) with other members of the social unit changes. The individual will come to view himself as more similar to certain individuals in the social unit and less similar to others. As this happens, interaction patterns will change and hence social structure.

## 4. ILLUSTRATIONS OF THIS APPROACH

There are many ways in which these methods/programs can be used to study the relationship between social and cognitive structures. In the following pages, some of these uses will be illustrated. Particular attention will be paid to testing and developing the forgoing theoretic model of decision making and cognitive development.

### 4.1. Relating Social Structure to Cognitive Structure

IDEA — In a social unit whose existence is not defined by the decision in question one would expect that the established pattern of interaction among the members of the social unit to affect the decision making behavior of the members of the social unit. One might even argue that the more established the group, the greater the potential for the underlying social structure to affect not only the particular decision making process, but the way in which the members of the group formulate that decision. When cognitive development is seen as the result of social interaction then the social structure of the social unit (as defined by the pattern of interaction) is expected to constrain the socio-cognitive pattern (as defined by the pattern of similarity in the cognitive structures of the members of the group). Roughly, the more two individuals interact the more they will share the same information. Moreover, the more similar the two individuals' patterns of interaction the more they will formulate the decision in the same way. Interaction leads to shared knowledge. Shared structural position leads to shared patterns of knowledge. If interaction levels are high and structural positions are similar then structural position will serve to re-enforce the knowledge gathered through individual interaction.

Hence, we would expect that the tighter the social sub-group (the higher the interaction among the members of the sub-group relative to the amount of inter-group interaction) the greater the pressure toward shared conceptions among sub-groups members. Further, given two tightly structured groups with little cross interaction the result should be divergent conceptions across sub-groups. Specifically, in sub-groups that are tightly internally structured — where the members of the sub-group spend the majority of their time with each other with little external contacts (e.g., cliques) — one would expect that the members of such sub-groups *vis-a-vis* a particular decision, would portray not only similar cognitive structures but structures that are not shared by non clique members.

The pattern of inter- and intra-group interaction that defines a clique should lead to members of the same clique having a shared formulation of the problem. Further, when there are opposing cliques; i.e., cliques which do not share fringe members you would expect to find that not only do the members of a particular clique share a common frame or formulation, but that the two cliques have different frames *vis-a-vis* the same problem. In contrast, in a loosely structured sub-group, a group where the inter- and intra-group interaction levels are both low, the degree of shared formulation should be basically random; i.e., the level of shared formulation should be no different than for any set of individuals chosen at random from the social unit. Whether or not members of a loosely structured sub-group share a fact is a chance occurrence.

DATA COLLECTION AND METHOD — Using a blocking procedure, CONCOR,* the students were divided on the basis of their interaction patterns into structural groups — groups whose members have similar patterns of interaction *vis-a-vis* all of the other members of the social unit.† For the following analysis the blocking into 10 sub-groups was chosen‡ see Table I for a description of these sub-groups.[5]

* To determine the internal socio-political structure of the social unit and the major sub-groups CONCOR is used (Breiger, 1975). CONCOR is a blocking algorithm which allows the researcher to locate structural groups relative to a set of social ties. The CONCOR algorithm is a method for hierarchically clustering relational data on the basis of the product-moment correlations. CONCOR produces blockings which are similar to and at times compatible with those produced by other blocking procedures — (White, 1976, Heil, 1976, Carrington, 1981).

CONCOR is used to subdivide the major groups into small groups. Each of these groups is composed of structurally similar individuals; i.e., individuals who are treated the same by the other groups and who treat the other groups in the same way. The purpose of dividing the hall as a whole and the major groups into smaller structurally similar sub-groups via CONCOR is to determine the underlying social structure, the network by which communication takes place.

† Cliques tend to be structural groups who have a high degree of interaction with all other members of the clique and very little interaction with any of the other members of the social unit. Another example of a structural group would be those individuals who have no interaction with anyone including each other (LONERS).

‡ The 10 block grouping is used as it is useful for illustrating the points about the relationship between social structure and cognitive structure that I want to make at this time. By

TABLE I
Structural Groups — A 10 block split

| Group ID Name | Group members | Density (close knit) Intra group | Inter group |
|---|---|---|---|
| F111: HEADS | JOHANN EUNICE JAKE | 1.00 | .117 |
| These students are into heavy rock music, drugs, and concerts. They are 60ish, outspoken, and not terribly studious. They were into burning things on the hall. | | | |
| F1121: LONERS | ZEBADIAH NOAH WOODIE | 0.00 | .027 |
| These students are very studious. Sometimes they attend hall meetings. They have extensive off all commitments. They are against drugs, drinking, and rarely attend hall parties. | | | |
| F1122: NON HALL | LAZARUS AARON ISHTAR HANS | 0.00 | .035 |
| These students spend a great deal of their socializing time with non hall members. They are fairly studious, and spend little time at hall parties. | | | |
| F121: DOERS | ERNEST MINERV A HILD A ZACCUR SLAYTON | .20 | .310 |
| These students are highly opinionated and speak out at hall meetings. They are willing to put action behind their ideas, and hence tend to run different services and to assume various leadership positions on and off the hall. | | | |
| F122: GNERDS | LOWELL GAY HAZEL | 1.00 | .172 |
| These students are very studious. They are anti drugs but do have expeditions to Fathers for beer. They attend hall parties, intramurals, and hall meetings. This group is often thought of as a family unit; especially since LOWELL and HAZEL got engage at the beginning of the year and were married at the end of the term. | | | |
| F211: SOCIALLY ACTIVE | IAN MEADE MAUREEN FREDERICO | .50 | .111 |
| These students tend to spend a great deal of time sitting in the lounges and walking up and down the hall socializing with other students. Most of their socializing goes on in different students rooms where they just walk in and start talking. | | | |
| F2121: SIDELINERS | EDITH LOWELL JOE MANNI | .33 | .125 |
| These students attend hall meetings and parties, but only as participants. They always have an opinion, but they rarely take charge of anything. These students do not instigate activities, and will often not evey help. However, they will often get involved in hacks. | | | |
| F2122: SELF DEFINED | LAFE ROGER JUSTIN DEETY | .17 | .131 |
| These students are all very well ensconced in non hall activities. While they do not rely on hall support; they do attend hall meetings, sometimes the parties, and take part in other hall activities. | | | |
| F221: LAID BACK | LORENZO JAQUES JUBAL | .67 | .334 |
| These students are mellow. They rarely force their opinions on others. They tend to spend a great deal of time socializing, most of it in the lounges. They like to hack the other students. | | | |
| F222: FRESHMEN | TAMARA CASTOR HANK POLLOX SAM THORBY TED | .67 | .114 |
| All of these students except HANK are freshmen. HANK is a sophomore who tends to associate mostly with freshmen. | | | |

Then for these groups for which there were coded maps for at least two members, joint maps were constructed,‖ and statistics gathered as to the similarity and differences between the individual maps.

Two of these sub-groups, the GNERDS and the HEADS,* are of special interest. These sub-groups are cliques; i.e., they exhibit a low/high pattern of inter-/intra-group interaction. The majority of their interaction is with members of their own group: they have an intra-group interaction rate of 1.0 at the close knit level — all of the students in the group said that they spent most or all of their time with the other members of the sub-group. Further, they rated all other students on the hall at a lower level of interaction. Not only were these two groups signaled as cliques by the blocking algorithm, but they were also the only two groups consistently mentioned as being cliques by the students in the interviews. The HEADS† are 60'ish type rebels who are perceived as spending more time partying than studying — long hair,

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using a 10 block split I am not suggesting that the hall is hopelessly fragmented, it is not. Nor am I suggesting that this split is technically the most accurate representation of the "real social structure". Rather, this split does show the range of interaction patterns that occur, and it allows extreme social behavior (e.g., cliques and loners) to be pulled apart from more typical social behavior.

§ Interaction rate data was collected by having the students fill out a questionnaire stating the amount of time, on a 5 point scale (never to always), that they spent interacting with each of the other individuals on the hall. From the original data, four matrices are created one for each type of tie between individuals — close knit, associated, rare interaction, and one unaware. These matrices are then stacked and CONCOR is used to find submatrices based on all four ties at once. CONCOR was then used to partition the data into 2, 4 8, and 10 block models (sets of structural groups). Then, after reviewing other characteristics of the groups — attitudes, academic ability, involvement, etc. — descriptive names were devised for each sub-group that reflected what I felt to be the sub-groups most salient social characteristic.

The approach outlined here is similar to that used by Breiger (1978) to analyze the social structure of scientists on the basis of mutual contact and unawareness. The interaction responses of the scientists were divided into three types of ties "mutual contact", "one unaware", and "both unaware". Then on the basis of all three types of ties at once, CONCOR was used to produce a model of the underlying social structure.

‖ The joint map is the map which represents the intersection of the individual maps.

* Note, the terms GNERDS and HEADS are common terms used by MIT students. The term HEADS was often used by students on Third East to refer to those individuals in the suggested group. The term GNERDS was not used explicitly for the other group, rather, in lieu of a better name, I simply used this name for this group.

† As noted in Table I there are 3 central members of this clique — Johann, Eunice, and Jake. Jake did not vote for a tutor and hence I do not have a final interview for him. Hence the joint map presented for the HEADS (diagram 7) is the joint map of Johann and Eunice.

jeans, drugs, loud music, the grateful dead. Whereas, the GNERDS‡ are conservative rising young engineers who appear to spend the majority of their time in their rooms studying — short hair, preppy, cords and sweaters, sunday afternoon football, and beer.

*4.1.1. Group Cohensiveness Leads to Cognitive Similarity* If, during the tutor selection process on Third East the social structure affected the formulation of the problem then the cognitive structures of the members of the cliques should exhibit a greater degree of similarity than the cognitive structures of members of structural groups with little interaction. In fact, the joint maps for the members of the tightly structured groups (the cliques: HEADS, diagram 7* and GNERDS, diagram 8†) are quite extensive; i.e., for both cliques intra-group cognitive similarity is quite high.

The GNERDS have an elaborate shared conception of the tutorship job, sharing 43 nodes, 127 connections as opposed to (23:76) for the HEADS. The greater elaboration in the intersection map for the GNERDS is due in part to a high degree of positive consensus between the cognitive maps of the members, not just the higher elaboration rate — the GNERDS share 55.84% of their nodes and 44.33% of their connections, as opposed to the HEADS (38.33%:25.42%). That is, the gnerds did not just mention more concepts, they were also more likely to tie those concepts together in the same way. Further, in terms of overall consensus, agreement over both what facts/concepts should be included and which should be excluded the effect of social structure is even more striking: GNERDS for concepts $\chi^2 = 91.58$ and for facts $\chi^2 = 261.45$, and then for the HEADS $\chi^2 = 61.47$ and $\chi^2 = 153.97$.*

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‡ As noted in Table I there are 3 central members of this clique — Lowell, Hazel, and Gay. Again, I do not have a final interview for Gay, and thus the joint map for the GNERDS (diagram 8) is just the joint map of Lowell and Hazel.

* This map is the intersection of the modified maps of Johann and Eunice at the end of the tutor selection process — time 3. The boxes indicate those concepts that are shared by both members of this clique and both members of the other clique.

† This map is the intersection of the modified maps of Lowell and Hazel at the end of the tutor selection process, time 3. The boxes indicate those concepts that are shared by both members of this clique and both members of the other clique.

* This chi-square, $\chi^2$, for concept is based on the $2 \times 2$ table containing: all of the concepts that both shared, those peculiar to person *x1*, those peculiar to person *x2*, and those concepts that neither had in their map. This last cell was found by subtracting the sum of the first three from the base population. The base population of concepts is 217; i.e., the only concepts that were felt to be available to the students to be included in their maps were those concepts that were in the social knowledge base. The same procedure is followed in constructing the chi-squared for the facts. For the facts, the base population is 1462, which is the number of facts available at time 3. Note, all of these chi-square are significant at the .05 level.

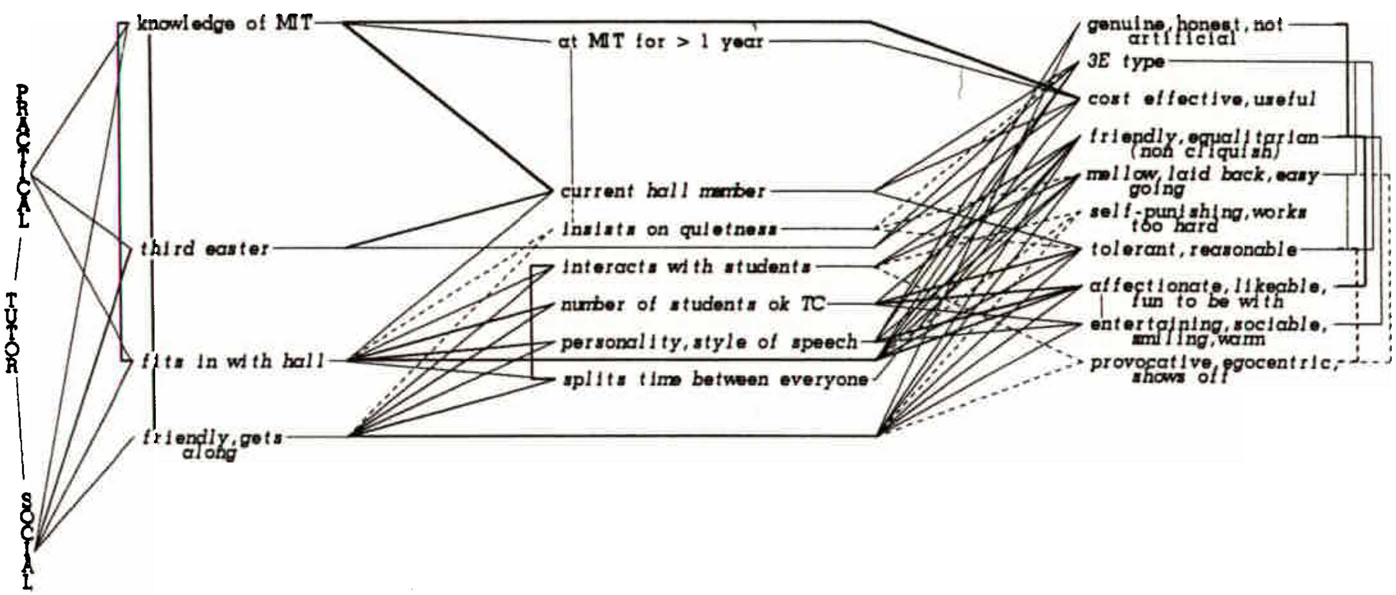


DIAGRAM 7 Heads' intersection map

This map represents the general knowledge about what it means to be a tutor on Third East that is shared by Johann and Eunice at the end of the tutor selection process, time 3. This map was produced by giving us input to SIMDIF the individual modified maps for Johann and Eunice and then getting as output the joint map for the two individuals. This joint map is the intersection of the two individual maps (INT) produced on a fact by fact basis. It represents the shared cognitive structure of the HEADS at time 3.

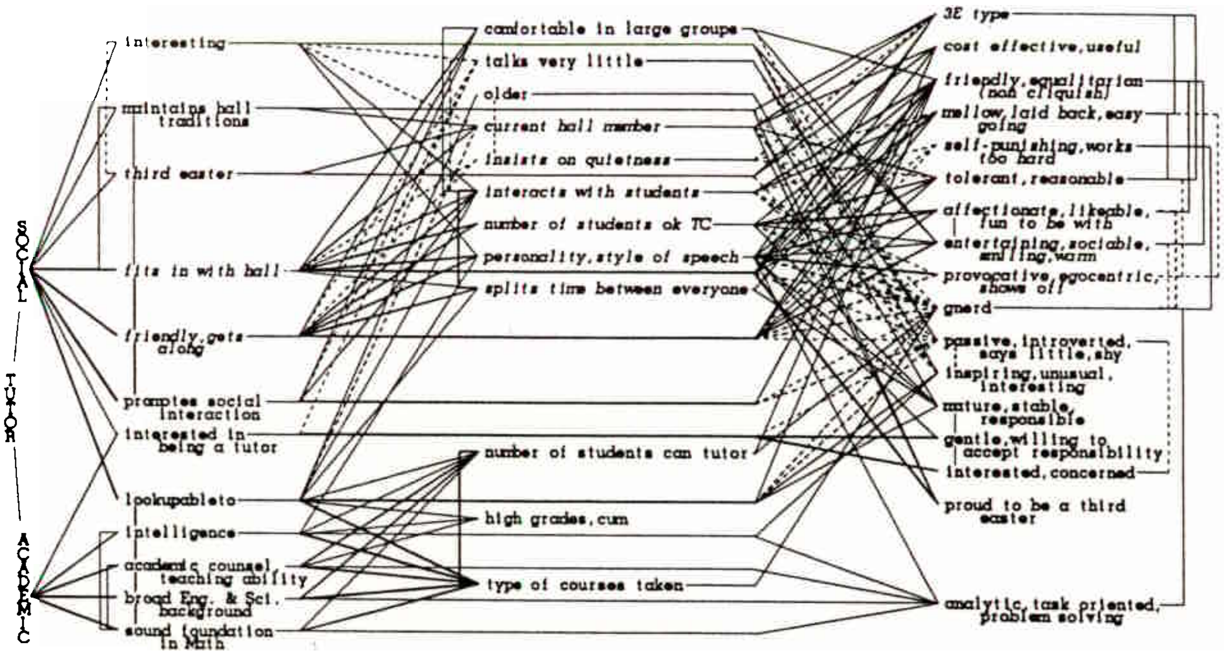


DIAGRAM 8 Gnerds' intersection map

This map represents the general knowledge about what it means to be a tutor on Third East that is shared by Lowell and Hazel at the end of the tutor selection process, time 3. This map was produced by giving as input to SIMDIF the individual modified maps for Lowell and Hazel and then getting as output the joint map for the two individuals. This joint map is the intersection of the two individual maps (INT) produced on a fact by fact basis. It represents the shared cognitive structure of the GNERDS at time 3.

These chi-squares indicate that the members of these groups formulate the concept tutor, define this job, in much the same way. While it is true that the only data available for these two sub-groups is that for the couples, the point is not that romantically involved couples see the world in much the same way. If the couple really saw the world in the same way, then we would expect them to vote for the same people. In point of fact, they did not. But, that is not the point either. The point is that the reason these individuals formulate the concept in the same way is because of their high degree of interaction. Being romantically involved may lead to a high degree of interaction, but it is the interaction, not the romance *per se*', that leads to the shared formulation. If you look ahead to Table II, you will see that the basic pattern is that as the level of interaction increases so does the observed similarity in the maps.

*4.1.2. Cognitive Distinctiveness* Another important point about the GNERDS and the HEADS is that not only are they the only two cliques on the hall, they have little interaction with each other. One student, Lorenzo, pointed out that there was a great deal of antagonism between the two groups "*Lowell* would not even mention *Johann's* name to anyone, he was just that unspeakable person next door." The two cliques tended to disagree on almost every issue that came up on the hall.

Not only do the members of the cliques have elaborate shared formulations of the tutorship job within their group, they also have distinctive elaborations. Just comparing the two diagrams, 7 and 8, one can see that the GNERDS have, e.g., an elaborated notion of the academic responsibilities of the tutor that is missing in the HEAD's map — someone who can provide academic counsel has a broad engineering and science background, a sound foundation in math, someone who is analytic, who gets high grades, and so on.

A stronger test of the distinctiveness of the shared conceptions would be to find all of those concepts and facts that were shared by both GNERDS and neither of the HEADS. Glancing at diagrams 7 and 8 we see that every concept which the HEADS use is also by the GNERDS, but not vice versa. Those concepts in italics in diagrams 7 and 8 are exactly those concepts which are in the other diagram; i.e., the set of concepts shared by the two groups. The non-italicized concepts can be thought of as representing the core distinguishing feature of this clique with regard to the tutorship job: those concepts in diagram 8 which are not italicized are concepts which are shared by all of the GNERDS and none of the HEADS. The point here is not just that the GNERDS use more concepts than the HEADS but that the resultant cognitive structures of the two groups are distinct.

The distinctive feature of those concepts shared only by the heads is that they all describe the tutorship job in terms of authority/responsibility. The GNERDS want someone who is older, mature, stable, willing to accept responsibility — in effect, a parental type figure. They also want someone who will maintain the hall's identity, proud to be a Third Easter, promoting social interaction (dragging people out of their rooms for study breaks and dinners) — in effect, a social leader. And they want someone who had taken all the right courses, could tutor a large number of people, who had a broad engineering, science, and math background — in effect, a kind of academic leader. By contrast, the distinguishing feature of the HEADS is that they *do not* see the tutor as an overall authoritarian responsible type figure. It is important to the GNERDS position in the social structure that the tutor control the hall and tutor the students. Such a tutor will promote an atmosphere which is conducive to gnerdliness. The HEADS on the other hand do not place emphasis on these features; e.g., it is not that they are against having a tutor who is very capable and willing to provide academic counsel, it is just not important to them.

As previously suggested, social differentiation in interaction has the potential of producing social cognitive instability; i.e., the difference in interaction rate between and within sub-groups actually causes the shared formulations of groups to diverge even through the cognitive structures of the members of the social unit as a whole are converging. The divergence of the shared cognitive structure provides a basis for sub-group identification, and hence control. This means that sub-groups, like concepts, are identified and defined relatively; i.e., the identity of a sub-group is dependent upon its relationship to other sub-groups *vis-a-vis* a particular decision not in terms of what decision is made but in terms of what information is shared. Given that all sub-groups are members of the same social unit there will be a minimum set of information shared by all individuals regardless of sub-group affiliation. At the socio-cognitive level lines of dissension will appear; i.e., set of concepts, sub-maps, will be associated with particular sub-groups and if the interaction patterns, in the short run, inhibit communication between sub-groups associated with different sub-maps then these concepts will become focal, used to identify the distinctiveness of the sub-groups, and hence serve as the lines of dissension. For example, at the beginning of the tutorship process the maps of the GNERDS and the HEADS differed slightly in terms of active social control (social responsibility) and academic ability. The GNERDS scoring high on both dimensions and the HEADS low on each. Other individual's on the hall had assorted perceptions of where the tutor should be *vis-a-vis* these two dimensions. As previously mentioned, the GNERDS and HEADS rarely communicated, and then only at social events such as hall meetings. By the end of the process students in sub-groups who interacted more with one clique than another tended to coalesce in the appropriate cognitive direction. By the end of the process, these issues were the major lines of debate. Moreover, one could identify at the end of the process major differences in the shared perceptions of the group members *vis-a-vis* other groups especially for the cliques and their immediate periphery.

So far, lines of cognitive difference have been discussed in terms of absolute differences (all of A and none of B); e.g., in terms of cognitive conceptions which uniquely identify one as being a GNERD as opposed to a HEAD. Such cores of distinction provide a basis by which membership in a group can be identified using strict logical rules. The distinctiveness of the GNERDS' versus the HEAD's conceptions of the role of the tutor goes beyond this strict core. There are average differences in conception, probabilistic tendencies; e.g., all of the HEADS, but only some of the GNERDS desire that the tutor have been at MIT for more than a year. The existence of both average and unique lines of disagreement provides a basis for social mobility on the grounds of cognitive similarity.

*4.1.3. Social Structure and Consensus — All Groups* As previously mentioned, if social structure affects cognitive structure then we would expect that those groups composed of individuals who do not spend much time interacting with each other to share fewer cognitive conceptions. Looking at Table II we see that this is in fact the case. In general, as sub-group cohesiveness decreases, cognitive consensus decreases. There is one outlier here, the DOERS, who although they have little interaction internally (.20 at the close knit level) have a high degree of consensus (100.80:327.71).

Why they should exhibit such a high degree of consensus is not entirely clear. It is probably the result of individuals who through similar positions in social networks external to the social unit have a high degree of shared conceptions even though there is little direct interaction. The DOERS tend to be very active students with many extracurricular non hall oriented activities; e.g., Zack is dorm president

TABLE II
Social structure and consensus

| Structural group | Intra-group interaction level | Consensus over concepts | Consensus over facts | Subset |
|---|---|---|---|---|
| GNERDS<br>Lowell, Hazel, Gay* | 1.00 | 91.58 | 261.45 | 0.82 |
| HEADS<br>Johann, Eunice, Jake* | 1.00 | 61.47 | 153.97 | 0.89 |
| LAID BACK<br>Lorenzo, Jaques, Jubal | 0.67 | 59.69 | 158.34 | 0.49 |
| FRESHMEN<br>Ted*, Thorby*, Castor, Sam*<br>Tamara*, Hank*, Pollox* | 0.67 | ? | ? | ? |
| SOCIALLY ACTIVE<br>Ian, Maureen, Meade*,<br>Frederico* | 0.50 | 56.97 | 111,56 | 0.68 |
| SIDELINERS<br>Edith, Manni, Jimmy*, Joe* | 0.33 | 44.29 | 102.36 | 0.46 |
| DOERS<br>Slayton*, Hilda*<br>Zaccur, Ernest, Minerva* | 0.20 | 100.80 | 327.71 | 0.25 |
| SELF DEFINED<br>Deety, Lafe*, Roger*, Justin* | 0.17 | ? | ? | ? |
| LONERS<br>Zebadiah, Woodie, Noah* | 0.00 | 49.40 | 73.46 | 0.13 |
| NON HALL<br>Aaron, Ishtar, Lazaraus* | 0.00 | 38.50 | 89.62 | 0.91 |
| NON STRUCTURAL<br>Zebadiah, Deety | 1.00 | 71.74 | 175.25 | 0.46 |

This table is based on individual maps (modified) coded from time 3 interviews. *'s indicate that the coded interview was not available at the time of this analysis.

and Ernest is heavily involved in his department. The two principles, Zack and Earnest, are both chemistry majors, have many friends off the hall — Zack through dormcon, and Ernest as he transferred to 3E from a different floor. To both of them, the tutor is a relatively uncrucial aspect of their MIT experience.

*4.1.4. Social Structure and Group Identity* As previously suggested, there should be a core of the shared cognitive structure for a clique that is not shared by non clique members. We have seen that this was the case for the GNERDS *vis-a-vis* the opposing clique, the HEADS. When the maps of the GNERDS are compared with those for all of the other students in the living group the GNERDS still retain such a core of distinction. For the GNERDS, this amounts to a single fact — someone who promotes social interaction is friendly, and will gets along on the hall.* Only the GNERDS maintained a positive core of distinction: they felt that promoting social interaction in the sense of actually forcing/controlling social interaction between students and getting along with the students on the floor, being friendly, were not only requirements for the job of being a tutor but were integral aspects of each other. The HEADS did not maintain such a positive core; however, there were facts that they did not have that most other members of the living group had. This suggests the possibility that there might be such a thing as a negative or shadow core of distinction. That is, a sub-group may be unique not by having special knowledge or ideas (core of distinction); but, by not a sharing the knowledge or ideas that all of the other members of the social unit shares (shadow core of distinction).

*4.1.5. Cognitive Domination* Shared frames among members of the sub-group serve to provide a basis for further communication and hence admit the potential for internal control. One measure of cognitive domination within a sub-group would be the degree to which a particular individual's cognitive structure dominates the others. In a particular decision, we might expect that the individual who controls the outcome, is the individual whose cognitive structure dominates. Given that cognitive development is a direct result of interaction, then in a tightly structured sub-group — a group where there is a high degree of intra-group interaction and a low degree of inter-group interaction — the stage is set for one of the individuals to cognitively dominate the others. High levels of interaction will lead to high levels of communication and individuals with more developed cognitive structures will have more information that they can communicate, more information that is "new" to the group, and so is potentially more able to control the decision by directing the cognitive development of other group member's frames because he has a wider choice of information that he can choose to communicate or not.

* Of the 19 time 3 interviews that were coded, the tie between promoting social interaction and friendly, gets along, was the only tie that both Lowell and Hazel shared and that no other students shared. This was found by first finding the union of the 17 other students using JOINT, finding the intersection for Lowell and Hazel's time 3 maps using, and then locating the symmetric difference map between these union maps for the living group and the intersection map for the clique. The resultant symmetric difference map for Lowell and Hazel contains exactly that structure which is unique to Lowell and Hazel at time 3.

The duplicity of aligning social ties leads to shared cognitive structure, it also provides the potential for one individual's cognitive map to dominate anothers. A very simple, and exploratory measure of cognitive domination is the degree to which one individual's map is a subset of the others; i.e., the individual whose map is contained in another person's map is dominated.

Consider the GNERDS, since they are a clique, a tightly structured sub-group, we would expect one of the members to cognitively dominate the other. Diagram 9 is Lowell's cognitive map at time 3 and Diagram 10 is Hazel's map also at time 3. Those concepts which are common to both, which are in the intersection map are in italics. As can be seen, Lowell's map clearly dominates in the sense that Hazel's map is basically a subset of Lowell's.

Using the notion of subset,* referring back to Table II, we see the general result that as group cohesiveness decreases, as the number of aligning social ties decreases, the degree to which one individual's map is a subset of the other's also decreases. Further, in the situation where the majority of interaction occurs within the group, and little between groups, as in the case of the cliques, the more likely it is for the cognitive map of one of the members of that group to dominate the others.

The exception here are the NON HALL oriented students. Here the resultant high subset value is almost an artifact of their personal cognitive style. To Aaron, the tutor was a very important job; e.g., not only did he come to use, the current tutors, with questions but he was also a close personal friend of the GNERDS and like them had the elaborate notion of the tutor as a parental/responsible/academic/leader type. Aaron's map was quite large, it included more of the concepts in the social vocabulary than other students' maps did. On the other hand, Ishtar spent the majority of her time off the hall. The tutor was relatively peripheral to her life, and she was not particularly close to any hall members. As a result, she had a very small map of the tutorship job.

*4.1.6. Duplicity of Structural Ties* Within the cliques, there is a definite pattern of domination — in the case of the GNERDS, Hazel's map is basically a subset of Lowell's (subset level = .82) and in the case of the HEADS, Eunice's map is basically a subset of Johann's (subset value = .89). Note, for members of less tightly structured sub-groups

* This is the ratio based on concepts. A similar measure could be made in terms of facts and it follows roughly the same pattern.

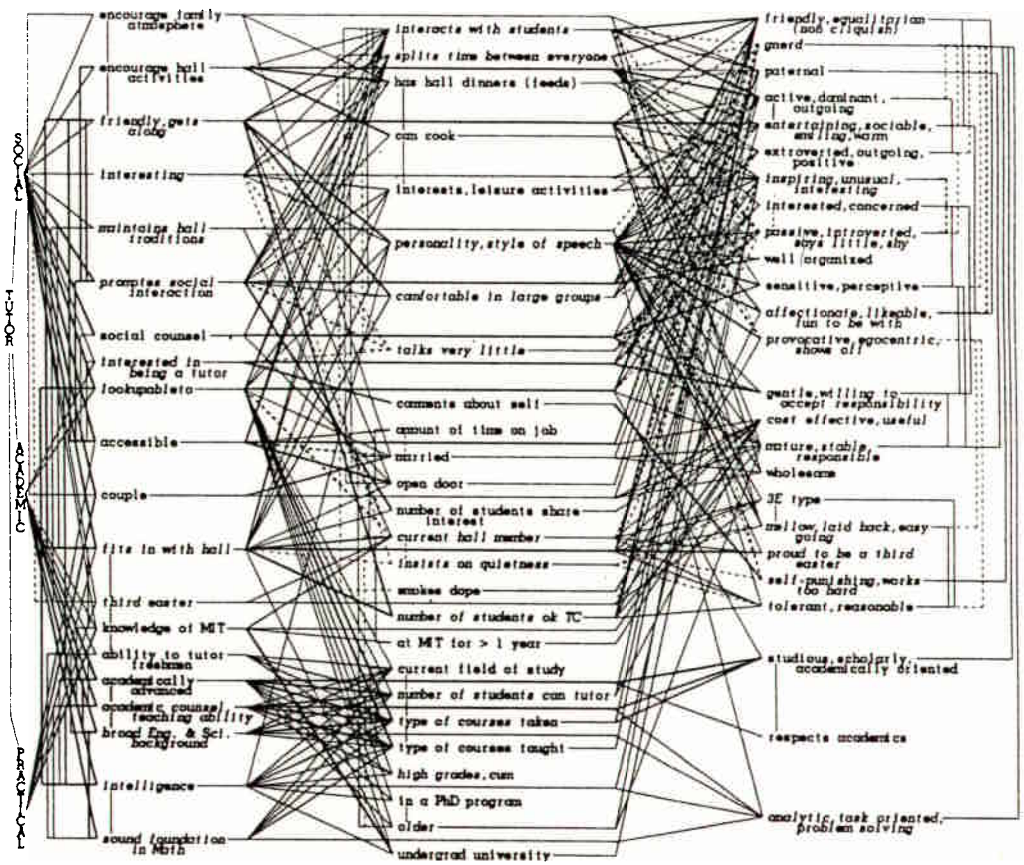


DIAGRAM 9 Lowell's time 3 map
This map was coded from Lowell's time 3 interview using CODEF and then modified using ADDSOC. It represents Lowell's general conception of what he wants in a tutor at the end of the tutor selection process.

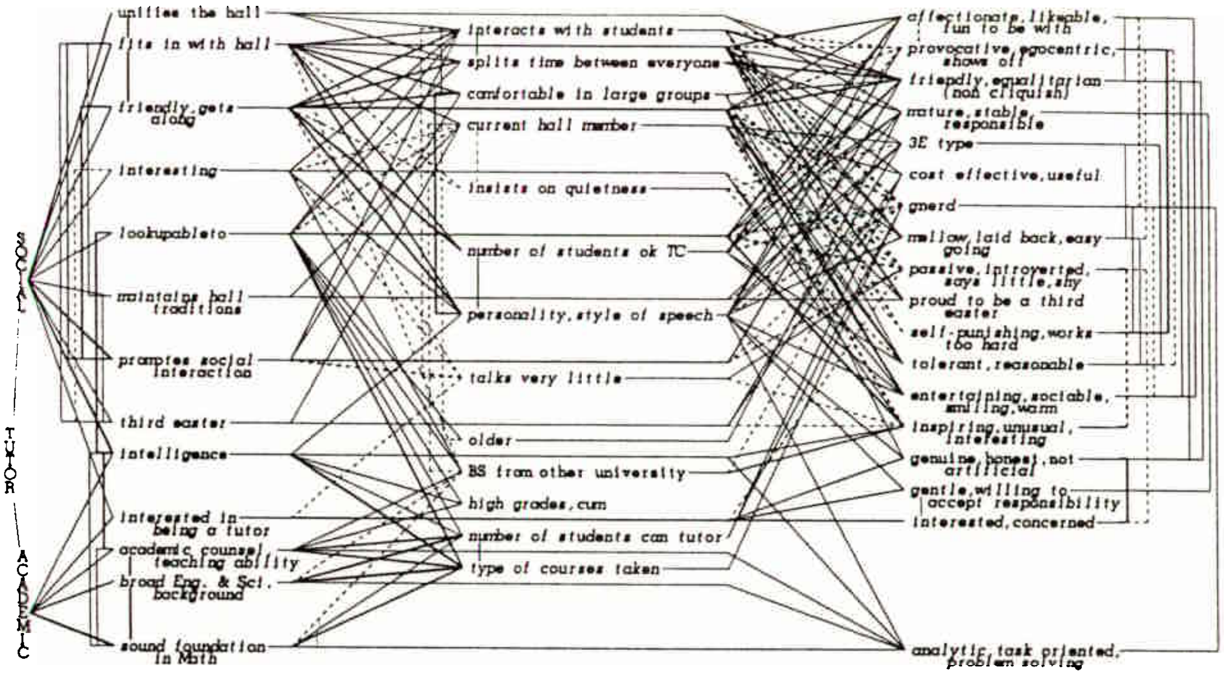


DIAGRAM 10 Hazels' time 3 map

This map was coded from Hazel's time 3 interview using CODEF and then modified using ADDSOC. It represents Hazel's general conception of what he wants in a tutor at the end of the tutor selection process. Note that Hazel's map is almost entirely a subset of Lowell's.

there is not a similar pattern of domination — refer to Table II; e.g., the LONERS have a subset value of only .22. That cognitive domination should occur is perhaps not so surprising as some of the facts behind the case. The poignancy of the argument is enhanced when one realizes that the core of each clique is a couple and that it is the male's map which dominates.* Lowell and Hazel were engaged during the year and planned to get married at the end of the term, and Johann and Eunice had been going together for about a year. Lowell and Hazel tend to be conservative, class and status orientated, and hard working in a standard motivation to get straight A's, get ahead in a job, sort of way; whereas, Johann and Eunice tended to be liberal, creative, 60's oriented, rebellious, mellow, and although they would work hard on topics which interested them, their interest came more from interest than social motivation. In both cases, based on personality profiles, there is reason to suspect that the male will dominate the situation. And despite the almost asymmetric socio-cultural background of the couples, it is the case that the females maps are subsets of the males.

Lowell comes from a middle class, blue collar background, wears a hard hat to parties, and is a hard working, conservative electrical engineer who acted as hall chairman his senior year. Hazel comes from a very proper and upperclass english background, and is bright, quiet, reserved, and traditional. In the case of the HEADS there is Johann who is from a very wealthy, somewhat academic background, who showed up his freshmen year with a car, stereo equipment, girls, and long frizzy hair. Eunice is a shy, timid girl, insecure and unsure of herself, a product of a slightly less well to do and more art oriented environment. Because Lowell and Johann exhibit more developed social personalities, and hold outgoing leader type positions on the hall, it seems that there is a potential for them to dominate their relationship with Hazel and Eunice, respectively, especially with regard to social issues. That is, it is possible that the cognitive domination that was

* Indeed, not only did the clique center around the couple, but due to unavoidable circumstances the only data that is available for coding is the set of individual interviews for the two people who happen to form the couple. Thus, the joint maps for these groups represent the conception of the tutorship job that is shared by the two members of the group who also happen to be a couple. Recall all individuals are interviewed separately. Couples are not jointly interviewed. When the two individuals are interviewed relative to each other is done randomly — sometimes they are interviewed on the same day, sometimes several days apart, etc., Therefore, any similarity in their coded interviews is a function of their communication with each other outside of the interview, not an artifact of the interviewing procedure itself.

observed for these groups may be a product of social psychological roles as opposed to structural position.

If this is the case, then we would expect that for another couple where the male held a similar psychological role *vis-a-vis* the female that a similar pattern of domination would occur. An alternative explanation for the apparent cognitive domination can be given in terms of social structure. The most striking fact about these cliques is that the members of the groups tend to interact primarily with each other and rarely with anyone outside the group; note, the ratio of internal to external interaction at the close knit level for GNERDS is 1 to .172 and for HEADS it is 1 to .117. In other words, the social ties that these individuals have align with each other and this alignment through decreasing external interaction increases the propensity toward cognitive domination. If this is the case, then the cognitive maps of individuals whose social ties do not align should exhibit less cognitive domination.

Zebadiah and Deety form a social pair with the requisite qualities. They are a couple who had been going together for over two and a half years where it is expected, based on their personality profiles, that the male will dominate. Zebadiah is a socially dominant leader type and Deety is a more quiet less forceful person. Zebadiah is wiry, strong, a member of R.O.T.C., went through ranger school for fun, from a very wealthy family, feels making a million a year would be merely comfortable, and was chairman of the student center committee his senior year. Deety is tiny, first generation chinese, quiet, well organized, likes to make cookies, studies hard, and is very reserved. From a structural perspective, Zebadiah and Deety are also a good choice as they are not members of the same structural group, they do not occupy similar positions in the social network. Hence, social ties do not align; i.e., although they spend a lot of time with each other, their patterns of interaction with other hall members are quite different — where Zebadiah spends most of his spare time alone or off the hall, Deety spends it socializing with other hall members.

From a role perspective, we might expect Zebadiah to dominate Deety; like Lowell and Johann, Zebadiah is the more socially dominant individual. However, from a structural perspective we would expect that Zebadiah would not dominate Deety nor would she dominate him as their social ties do not align. In looking at the last row in table II we find that in fact neither individual does dominate the other; i.e., while they do have a high degree of consensus in their conceptions of the tutorship job (71.74:175.25) neither's map is a subset of the other (.46).

## 4.2. Social Structure Across Time

IDEA — Overtime, cognitive structures are elaborated through the influx of information. Indeed, one of the primary characteristics of social decision making processes is that the members of the social unit are being bombarded by new information. Specifically, over the course of a decision making process, as new information comes in, it is natural that some of this information is acknowledged by the individuals and accepted into their cognitive structure. This elaboration is not random but specifically defined by the structure of the social unit, and the flow of information from external sources throughout the decision making process. Another thing that can be done with the methods previously described is to trace the development of cognitive maps over time and to begin to gauge the relative affect of group and external influences on this development.

DATA COLLECTION AND METHOD — As previously described each of the students were interviewed several times throughout the tutor selection process. In this section, maps obtained from time 1 interviews (beginning of the process before specific tutor candidates were selected) are compared with those obtained from time 3 interviews (after the students voted on the candidates). Then differences in time 1 and 3 maps were located using the programs previously discussed.

*4.2.1. Consensus Building* In a tightly structured sub-group it is expected that over time the members of the clique will develop more similar cognitive structures. The high degree of intra-group interaction relative to inter-group interaction serves over time to produce consensus by limiting the number of information sources. For both of the cliques there was an increase in consensus over time; i.e., the maps for the members of the group became more alike — an increase in similarity of 32.5% for the GNERDS and 30.0% for the HEADS.*

This increase in consensus is the result of social structure. Again, if it was merely due to the fact that the nexus of the group was a couple who spent a large amount of time together, then we would expect that over time Zebadiah's and Deety's maps would become more alike. Whereas, Zebadiah's and Deety's maps actually decreased in similarity (–13.6%) during the course of the tutor selection process. This suggests that although interaction is necessary for shared information,

* Note, this is the percentage increase in the chi-squared for concepts.

consensus is only produced if social ties overlap, if individuals have similar social positions, are members of the same structural group. Social structure, not social role appears to determine consensus.

*4.2.2. Consensus and Control* Let us take a moment here to rethink the issue of domination. It was suggested in the last section that Lowell apparently dominated Hazel and Johann, Eunice; because, in looking at their time 3 interviews we saw that Hazel's map is a subset of Lowell's and Eunice's of Johann's. However, when we look at the pattern over time, we see that the reason that the girls' maps are subsets of the guys' is that the guys have added to their time 1 maps many of those concepts that the girls felt were important (group impact), and the girls dropped many of the concepts that guys felt were unimportant (group impact) — see Table III.

There seem to be two processes going on here: (1) cognitive elaboration and (2) social irrelevancy. Cognitive elaboration is the process whereby individual's add information to their current knowledge base or frame.* Social irrelevancy is the process whereby individuals do not focus on information which they have in their frame because they feel it is irrelevant to the problem at hand.† Note that the group effect is consistently greater than the non-group or outside influence effect only in the case of dropping concepts. That is, the group *per se* seems to have more of an influence on the individual in terms of convincing them that particular information is irrelevant rather than in terms of elaboration. The data presented above suggests that, for this particular social unit, the girls are more likely to begin with a fairly well developed notion of what they want in a tutor and the guys are likely to develop/elaborate their frame by incorporating the information communicated to them by the girls. Whereas, the girls are more likely to decide that information in their initial cognitive structure is socially irrelevant and hence stop communicating it, if that information is not in the guys map.

### 4.3. Dynamic Evolution of Social Knowledge

IDEA — In general, the processes outlined above determine the dynamic evolution of individual cognitive structures. Through these

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* For more information refer to (Carley, 1985a).

† There is no reason that we should expect that individuals actually forget particular facts; rather, that a particular concept does not occur in a particular discussion is perhaps better attributed to it being considered irrelevant at that point in time, or at least to not being focused on.

TABLE III
Patterns of cognitive development

| Structural group | | Concepts added to time 3 maps | | | Concepts in time 1 & 3 | | Concepts dropped from time 3 maps | | | Total concepts in map |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Group impact | New to both | Outside impact | Joint core | Self core | Group impact | Both dropped | Outside impact | |
| | Lowell | 25 | 10 | 15 | 18 | 6 | 4 | 3 | 0 | 81 T1&T3 |
| | | 33.78% | 13.51% | 20.27% | 24.32% | 8.11% | | | | 74 Time 3 |
| Gnerds | | | | | 58.06% | 25.81% | 12.90% | 9.68% | 0.00% | 31 Time 1 |
| | Hazel | 1 | 10 | 3 | 18 | 14 | 16 | 3 | 3 | 68 T1&T3 |
| | | 2.17% | 21.74% | 6.52% | 39.13% | 30.43% | | | | 46 Time 3 |
| | | | | | 33.33% | 25.93% | 29.63% | 5.56% | 5.56% | 54 Time 1 |
| | Johann | 9 | 7 | 16 | 11 | 15 | 10 | 3 | 0 | 71 T1&T3 |
| | | 15.52% | 12.07% | 27.59% | 18.97% | 25.86% | | | | 58 Time 3 |
| Heads | | | | | 28.21% | 38.46% | 25.64% | 7.69% | 0.00% | 39 Time 1 |
| | Eunice | 2 | 7 | 2 | 11 | 3 | 14 | 3 | 5 | 47 T1&T3 |
| | | 8.00% | 28.00% | 8.00% | 44.00% | 12.00% | | | | 25 Time 3 |
| | | | | | 30.56% | 8.33% | 38.89% | 8.33% | 13.89% | 36 Time 1 |
| | Zebadiah | 3 | 3 | 6 | 42 | 6 | 8 | 5 | 5 | 76 T1&T3 |
| | | 5.17% | 1.72% | 10.34% | 72.41% | 10.34% | | | | 58 Time 3 |
| Non structural | | | | | 63.64% | 9.09% | 12.12% | 7.58% | 7.58% | 66 Time 1 |
| | Deety | 7 | 1 | 20 | 42 | 7 | 19 | 5 | 2 | 103 T1&T3 |
| | | 9.09% | 1.30% | 25.97% | 54.55% | 9.09% | | | | 77 Time 3 |
| | | | | | 56.00% | 9.33% | 25.33% | 6.67% | 2.67% | 75 Time 1 |

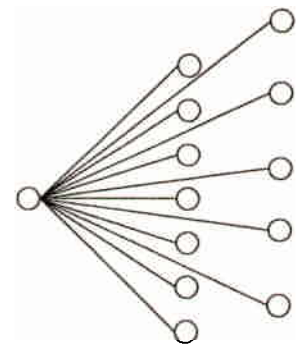
Numbers in boxes are:
Number of concepts
% of concepts in time 3 map
% of concepts in time 1 map

processes, the actual meaning of concepts change over time by both new concepts being added to the structural definition and old concepts being expunged. In general, we might expect that the rate of addition is higher than the rate of subtraction as to add a concept requires the addition of a single fact, whereas the deletion of a single concept requires the individual to consider irrelevant all the facts that involve that concept. In Table III we saw that on average 24.5 concepts were added at time 3, and 18 concepts became irrelevant. This suggests, that over time, communication of a particular cognitive structure will become increasingly difficult as it will involve the communication of a rapidly growing set of concepts.

DATA COLLECTION AND METHOD — Using the social knowledge base, the set of facts which everyone knows, and the methods previously described it is possible to analyze this social data to determine whether or not this difficulty will in fact occur. As previously noted, the social background information is used to construct a general social knowledge base. Then, using GENSOC the social maps (definitions) for each concept in this knowledge base are extracted. Then for each concept its network properties *vis-a-vis* the social knowledge base are calculated. Two of the properties that concepts have are cognitive density and cognitive transitivity — see diagram 11. Cognitive density is the degree to which a particular concept connects to other concepts; i.e., the number of facts that include this concept. Cognitive transitivity is the degree to which a particular concept connects other concepts; i.e., the number of paths through this concept. Note, since the connections between concepts can go in either or both directions, any concept, even the focal decision concept, can exhibit high cognitive transitivity or density. Then, using a Euclidean combining metric on the various network properties the concepts are clustered.

*4.3.1. Robust Social Knowledge* An analysis of the properties of the concepts in the social knowledge base suggests that the social language, the functional language of social communication, has an underlying robust structure that admits the potential for rapid communication despite the number of concepts involved. In terms of social background information, concepts which are cognitively very dense allow rapid communication as if one individual brings them up the other individual will instantly have access to not only that concept but all of the other concepts in the social background information that are connected to this concept. Examples of cognitively dense concepts are stereotypes. If

COGNITIVE DENSITY



COGNITIVE TRANSITIVITY

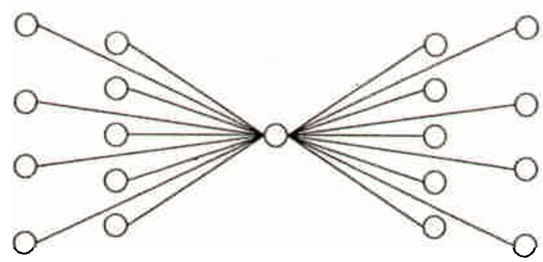


DIAGRAM 11 Cognitive network properties of concepts
At the cognitive level, all concepts only have meaning by their relationship to other concepts. Hence, we can think of concepts as nodes in a network. As such, they have two distinct properties — density and transitivity. Cognitive density occurs when a concept is highly connected to other concepts in the knowledge base; i.e., the concept occurs in a large number of facts. Cognitive transitivity occurs when a concept has a large number of paths in the knowledge base that flow through it. Highly transitive concepts are socially useful in that they admit rapid communication. In this diagram, the nodes represent the concepts, and the lines represent the relationships between the concepts. Note, these relationships can occur in any direction, regardless of the concept's position in the frame or map.

one individual uses a stereotype when explaining his views the other members of the social unit will instantly have a clear map of what that individual is apparently saying. Thus, cognitively dense concepts allow the rapid transmittal of portions of maps. This is not to say that the maps are accurately communicated, rather that they are rapidly communicated. In these terms we can think of errors or noise in communication as that information which is carried through social background information that is not in the individual's map to begin with.

Highly cognitively transitive concepts admit rapid communication both because they conjure up a large number of other concepts and because they can be conjured in a large number of ways. Highly transitive concepts are also likely to be those concepts which have the highest social usage. They are the most likely to occur in individual maps because they can be brought in either to define another concept or as the concept which is defined.

In diagram 12 the result of the clustering is presented with respect to the properties of cognitive density and transitivity. Each cluster is represented by a two dimensional Gaussian curve. The height of each peak represents the number of concepts in that cluster. The standard deviation in each coordinate is the standard deviation of the cluster along that variable.

Most concepts are low in both dimensions. There are very few concepts which are both highly cognitively dense and highly transitive, of which, the most extreme is the concept *mellow, laid back*. As was suggested, the most cognitively dense concepts are stereotypes — *expert*, *gnerd*, *hacker*, and *phantom*. Those words that are highly transitive are vague definitional terms — *personality*, *style of speech*, *interacts with others*, *insists on quietness*, *fits in with the hall*, *friendly*, etc.

As was previously mentioned, we would expect that the highly transitive concepts will be the socially most visible; i.e., everyone will have them in there individual maps. The map in diagram 13 is the intersection of the 19 maps that were available from time 3 interviews. This map represents the general consensus of the minimum tutor requirements: this map represents the set of facts and concepts that every individual in the social unit felt was important in formulating the tutor selection decision.

Every single highly cognitively transitive concept is in this map. Further, of the 10 concepts in this map, only two of these concepts are not members of the highly transitive group of concepts — the concept *social* and the concept *number of students who ok the tutor candidate*.

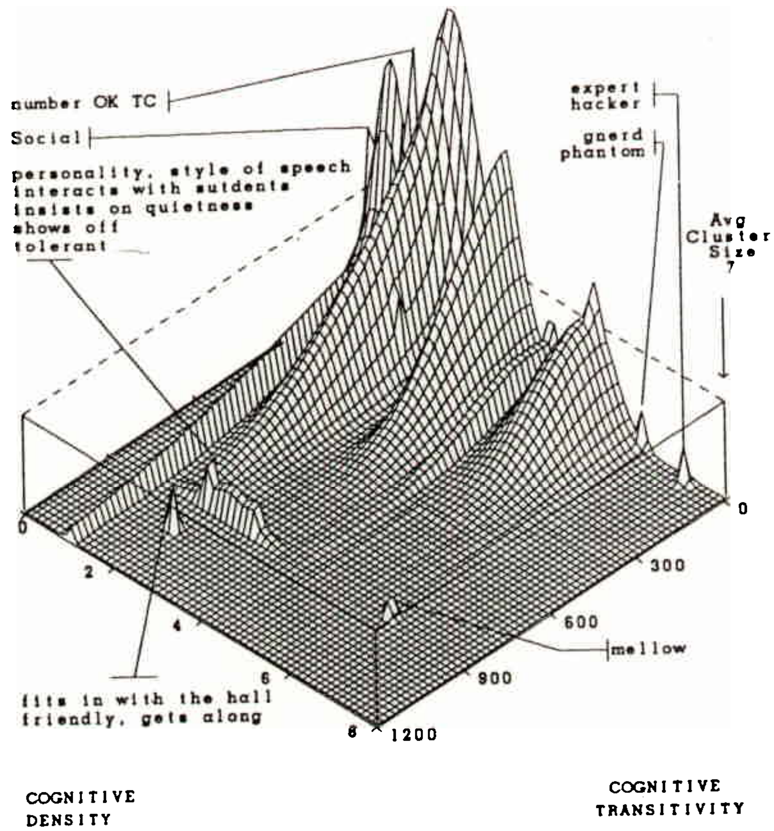



DIAGRAM 12 Clustering of concepts along transitivity and density
The group of 29 clusters produced using a euclidean combining metric on the standardized parameters — density and transitivity — is topographically presented using density, transitivity, and cluster size as the axes. Each cluster is represented as a two dimensional Gaussian, with the height being proportional to the number of concepts in the cluster and the breadth in each dimension being proportional to the standard deviation of the concepts in that cluster on that dimension. Concepts high in transitivity should be highly utilized by the members of the social unit as they are implied by a large number of concepts, and in turn imply a large number of other concepts. They admit ready consensus over the nexus of an idea without fully specifying its' form. Concepts high in density are very rich concepts, concepts which if used evoke a highly specified well agreed to image. Note, the stereotypes *expert, hacker, gnerd*, and *phantom* all stand out as being highly dense concepts.

The first of these concept — *social* — is an artifact of the coding process. For ease in coding I created the broad general concept categories social, academic, administrative, and practical. These artificial concepts aid in the analysis by providing structure to the maps and make it easier to display the maps graphically; however, they are constructed to have low transitivity as they can proceed on the one side only to the decision point and on the other are not allowed to define any concepts *a priori* so that they will not force the map to include any particular concepts.

The other additional concept — *the number of students who ok the tutor candidate* — is the result of **social learning**. Recall, that it was suggested that the social knowledge base would change over time as all of the individuals came to incorporate new information in their individual cognitive structures; i.e., the influx of external information could result in the elaboration of the cognitive structures of the individuals, and as all (or the majority) of the individual cognitive structures developed the new information became a piece of social knowledge. This tutor ok'ing concept is the result of such a process. An event occurred during the *tutor selection process* that altered the knowledge structures of all of the students on the hall.

One of the tutor candidates after his hall interviewee went into a room with the HEADS to smoke dope. This upset a large number of students on the hall; some felt that the tutor *shouldn't do drugs*, others felt that any one who spent time with the heads wouldn't be a good tutor, and so on. This event became the topic of a large number of informal and formal meetings. What worried the majority of the students the most, was that the candidate could cause conflict, albeit inadvertently. They argued that anyone who caused conflict among the students might take sides on other social issues, might be cliquish. It thus became important to the students that the tutor be someone whom everyone (or at least a large majority) liked. It became important how many other students liked the candidate. The tutor selection criteria moved from *this will affect me* to *this will affect us*. Ergo, the concept *the number of students who ok the tutor candidate* became an important concept and was incorporated into all of the individual's maps.

## 5. SUMMARY

In this brief overview I have tried to present a new way of looking at group decisions wherein the crux of the problem has been shifted to the

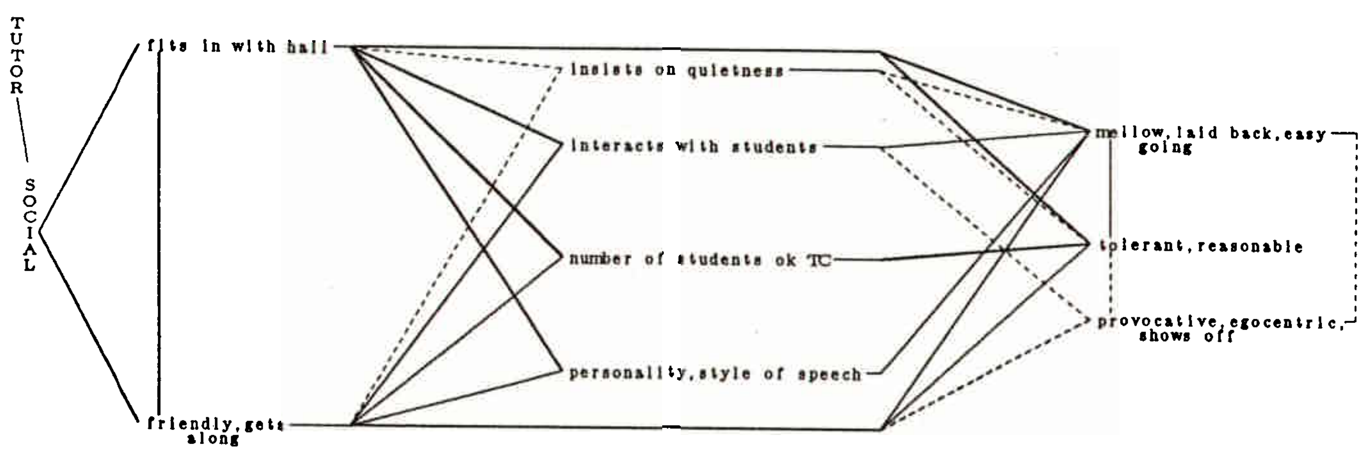



DIAGRAM 13 Joint time 3 map for all 19 students
The time 3 maps for the 19 students whose maps were coded using CODEF and then modified using ADDSOC were combined using SIMDIF to create a joint map. This joint map represents the intersection of the individual maps at the end of the tutor selection process. It can be thought of as the consensus of individual attitudes over the concept tutor that has emerged during the tutor selection process.

formulation of the problem. A set of methods based on these substantive notions were presented and then utilized to explore the relationship between social structure and cognitive consensus among the students on Third East as they selected a new tutor. As a result, there are experimental outcomes as well as substantive and methodological ones.

*Major Substantive Points*

- Decision making is a primarily formulative process.
- Social, cognitive, and evaluative structures can't be decoupled if we are to be understand the process of individual decision making.
- At least in the short run, cognitive development is a byproduct of social interaction.
- The social knowledge base and the social structure are affected by individual cognitive development in a recursive fashion.

*Major Methodological Points*

- *Frame Technology* provides the user with a language for dealing with frame like structures.
- This language is powerful because it possesses the property that there is closure over the means of combination; i.e., the input and output for the procedures that combine maps are in themselves maps.

*Experimental Outcomes*

Tight social structure (a structure where social ties align such that there is high internal interaction compared to external interaction) affects cognitive development. Specifically,

- The tighter the social structure the greater the degree of cognitive consensus.
- The tighter the social structure the greater the potential for cognitive domination.

And, linguistically,

- Highly cognitively transitive concepts are the most likely concepts to be used by all of the individuals in the society.

The empirical data is exploratory, and the outcomes open to debate. Further research will be needed to verify and clarify the trends observed in this exploratory study. Frame technology is seen as a set of methods which can be used to explore questions about the relationship between social and cognitive structure, like the questions looked at herein, in an empirical fashion. I suggest that these methods are more consistent with the realities of social decision making processes than those methods which are based on a less socio-cognitive non formulative view of decision making. In particular the ability to analyze individual's perceptions not just in terms of the words they use, but in terms of the inter-relationships between those words and the ability to combine maps makes it possible to study how who one knows affects what one knows at an empirical level heretofore impractical.

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