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A DESIGN-INTERPRETATION ANALYSIS OF NATURAL ENGLISH-WITH APPLIC--ETC(U)
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Research Report

A DESIGN-INTERPRETATION ANALYSIS OF NATURAL ENGLISH*

WITH APPLICATIONS TO MAN-COMPUTER INTERACTION

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ABSTRACT. Many behavioral scientists and most designers of man-computer interfaces view communication in a certain way. This viewpoint includes the implicit belief that communication from system A to system B essentially involves the encoding of some internal state in system A into an external statement for transmission to system B. System B decodes this message and changes its internal state. Communication is considered 'good' to the extent that there is an isomorphism between the internal states of the two systems after the message has been sent. This paper argues that this view is inadequate both for an understanding of communication between two persons and as a theoretical foundation for any kind of man-computer interaction, particularly in natural language. Empirical results supporting this proposition are reported. In addition, an alternative view of the communication process is outlined. This view stresses the game-theoretic aspects of communication, the importance of viewing message-building as a *constructive* (rather than translational) process, the importance of metacomments, the multiplicity of channels involved in human natural language communication, and stresses that, under certain conditions, the 'vagueness', 'fuzziness' and ambiguity of natural language are assets, not liabilities. The paper concludes by discussing some ways these ideas could serve as possible guidelines for the design of man-computer interfaces. A major purpose of the paper is to encourage the expression of alternative views on these issues.

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A Design-Interpretation Analysis of Natural English
With Applications to Man-Computer Interaction.

1. Introduction and Background

1.1 Outline of the Paper.

This paper is organized according to the following plan. First, some general results from psychology will be presented as background material. In particular, results are discussed that indicate the manner in which an understanding of the goals of individuals helps predict their behavior. In addition, the utility and limitations of information theory as a tool for understanding human capabilities are discussed. Second, a common, though usually implicit, model of communication is outlined. Third, an alternative model is presented. Fourth, some implications of this alternative model for man-computer communication are explored.

The ideas presented here are not intended to comprise a complete model of human communication; rather they point to omissions in many current viewpoints. Furthermore, the author has not been able to organize these ideas into a compelling Gestalt. At this point, the important, but overlooked properties of human communication seem to structure themselves simply as a heterogeneous list. The author welcomes criticism as a means of refining and reformulating the issues discussed in this paper. Far from being intended as the 'last word', a major purpose of the paper is to solicit ideas from people in the many disciplines concerned with man-computer interaction.

1.2 *Game Theory*

When complex systems interact, conflicts or tradeoffs between goals are typical. Game theory provides a conceptual framework for viewing such interactions including the special case of natural language communication.

1.2.1 Background. To the first approximation, human behavior can be fairly well predicted from a knowledge of the goals of a person and the relationship between his capabilities and the complexity of the environment. If we know, for example, that a person wants very much to learn to program in FORTRAN, and we know that there are no particular environmental barriers, and we know that the complexity of the task is not prohibitive given his or her capabilities, we can fairly well predict that the person will learn to program in FORTRAN. Of course, there are a number of non-trivial issues involved in this prediction. How does one determine what another's goals are? How does one measure the complexity of the task or the capabilities of the person? Nevertheless, using such an informal theory, people are often able to predict much about the behavior of others in complex real-world situations. Psychology has expended considerable effort in attempting to measure the capabilities of people, both in terms of general limitations, and in terms of individual differences. Rather less effort has been spent in characterizing the tasks that people engage in. The least effort of all has been expended in understanding people's goals. Yet, it will be argued below that an appreciation of people's goals is vital to an understanding of the communication strategies that they employ.

One of the best theoretical tools for dealing with interactions between goal-directed systems is game theory (von Neumann and Morgenstern, 1953; Davis, 1970). Though most real life situations are too complex to be analyzed in detail using game theory, nevertheless, the theoretical notions in game theory are useful for an understanding of what can happen in

communication (e.g., the fact that in a non-zero sum game it can be to your advantage to move first).

Game theory provides a framework for discussing conflict. Conflict can exist between or within individuals and groups. When a person interacts with the environment, for example, a conflict typically exists between the desire to maximize his or her influence on the environment (including other people) and the desire to minimize the extent to which the environment influences the person. One desire seeks to maximize interaction and the other to minimize it. Ideally, a person would like to have knowledge about the nature of the interaction and be able to control the interaction. Since a person's knowledge and control are finite, however, some degree of conflict typically exists concerning the optimal level of interaction.

Another level of conflict often exists because a person is simultaneously operating *qua* individual and as a member of other systems. As a member of a basketball team, for example, a player's best strategy may be to allow himself or herself to be influenced so as to increase the payoffs that will accrue to the entire team and its members. As an individual, the player may want to maximize personal influence. Another example of wanting to be influenced by others occurs when one wants to be taught so that one may react better to the environment. This is possible because of partially shared viewpoints of reality and the fact that there is not a perfectly competitive situation between those who teach and those who learn. On the other hand, there are limits to the extent one is willing to change in a learning situation. In fact, generally there is a conflict between opening oneself to influence via communication and defending against such influence. There may be special cases in which one may safely ignore this conflict but those special cases should not be treated as paradigmatic.

The view that people are communicating in order to meet their own (sometimes conflicting) goals in no way presupposes that goals are blindly egocentric and self-serving. Naturally, there are cases in which one's goal is to help or to please another. While it is not valid to

consider every act of communication as occurring in a context of pure cooperation, it is equally misleading to view every act of communication as a move in a zero-sum game. We are probably only rarely involved in true zero-sum games. One man's loss is not necessarily another's gain and vice versa as sometimes popularly supposed.

1.2.2 Effects on Communication. What are the ramifications of postulating that every interaction between two separate systems (e.g., two humans engaged in dialogue) depends upon the goals of the systems? One implication is methodological: to be properly understood, all communication, including natural language communication, must be analysed under conditions wherein the major goals of the communicators are known. In the psychological laboratory, goals are most commonly manipulated through instructions to the subjects. Persons reading written materials understand differently depending upon instructions (Fredricksen, 1975). Below are two further simple examples of situations in which the game-theoretic aspects of the situation strongly affect the communications.

1.2.3 Quantification Experiments. Earlier work in our laboratory (Thomas and Gould, 1975; Thomas, 1976a) indicated that people had considerable difficulty dealing with concepts of quantification (e.g., All X are Y). This is consistent with many other studies of thinking (e.g., Niemark & Chapman, 1975; Wason & Johnson-Laird, 1972). One of the difficulties people had was in unambiguously describing basic set relations (e.g., A is a subset of B; A and B are disjoint sets). In order to assess the effects of the game-theoretic situation on quantified expressions, an experiment was performed in which pairs of people communicated via teletype. Initially, each subject was presented with some information concerning the relationship between two sets. One subject, the 'receiver' was given information that was variously complete, incomplete, or inaccurate. The other subject, 'the sender' was given a replica of that information as well as a complete accurate description of the true set relation. The task of the 'sender' was to send a message to the receiver about the set relation. The receiver's task was to combine his previous information with the message he received and then to draw a Venn

diagram that showed the true set relation. Subjects communicated about set relations under either a competitive or cooperative arrangement. (Further details of the experiment are given in Appendix A). In all cases though, the 'sender' was required to send true, relevant information.

For the purposes of the present discussion, three points are of interest. First of all, the subjects with complete information behaved quite differently under the two conditions. For example, when the two sets were actually disjoint and the subjects were in the cooperative condition, the other subject (the 'receiver') managed to produce the correct Venn diagram 92 per cent of the time, while in the case wherein the subjects were competing, the receiver drew the correct diagram only 56 per cent of the time. For each of the five set relations, the drawer (receiver) was nearly twice as accurate in the cooperative situation as in the competitive situation. This was despite the fact that senders were constrained to give truthful, informative statements even in the competitive situations. However, the sender was not as informative in the competitive situation. Though these results may strike the reader as obvious, many, if not most, academic writings on communication ignore the game theoretic aspects of the communicative situation, or mention it briefly in passing. The above result, however, supports the notion that the message that a person will produce depends heavily upon the game-theoretic aspects of the situation.

The second point of interest is that the statements that subjects chose to transmit depended, in both situations, upon the knowledge the other subject already had available (cf. Olsen, 1970). This important point will be developed later.

The third important point is that the receivers of the communications responded to identical combinations of messages-and-prior-information differently depending upon whether they perceived the situation as cooperative or competitive.

In summary, the messages that people send (even when constrained to send messages that are true and relevant) and the interpretations put on these messages both depend upon the goals of the communicators and upon the prior knowledge of the person to receive the message.

1.2.4 Power patterns in Question-asking. The socially allowable conversational strategies depend upon the power relations of the people involved. For example, it has been observed (Mischler, 1975) that children are expected to respond to teacher's questions with answers or possibly with clarifying questions. On the other hand, a teacher is perfectly free to respond to a child's question with another question. For example, the following conversation is perfectly acceptable:

CHILD: How does a steam engine work?

TEACHER: What happened in science class yesterday?

The following conversation could easily result in corporal punishment.

TEACHER: How does a steam engine work?

CHILD: What happened in science class yesterday?

Similar restrictions apply to conversations between client and psychiatrist, sergeant and corporal, employer and employee. In each case, the person with more power can ask virtually any kind of question including rhetorical questions and those that clearly change the topic. The person with less power is limited to clarifying questions, or clearly topic-relevant requests for specific information. The tutorial dialogues given by Collins (1976) illustrate these rules. In fact, when the student asks a more general question, the tutor regains control as in the following exchange (Collins, 1976).

TUTOR: And do you know why?

STUDENT: Why?

TUTOR: Why is the farming at a disadvantage?

1.3 Man as an Information Processor.

Information theory is obviously of tremendous importance to many types of engineering concerned with the building of computers. In an attempt to provide a unified framework for understanding the capacity limitations of human beings, psychologists attempted to apply information theory to the cognitive processes of humans. Within very limited paradigms, one can predict the performance of people from a consideration of the number of bits of information processed. (See Fitts and Posner, 1967 for some examples). Unfortunately, things are just not that simple in the general case. A number of studies have indicated that better predictions of human performance result from considering the number of symbols processed, rather than the the number of bits (See Miller, 1956).

Despite the fact that it has been clear for at least a decade that it is only useful to discuss man-computer interaction in terms of bits under extremely limited circumstances, the belief that a scientific, quantitative analysis of cognitive processes can be usefully measured in bits/second continues to be expressed. This is particularly surprising (but therefore highly informative) since psychologists were generally aware of these limitations even during the 'heyday' of the application of information theory to psychology. (See, e.g., the preface in Attneave, 1959). The performance of people in all but the simplest laboratory situations depends upon the strategies that people use and the internal symbols that they have available. For example, in the domain of chess, it has been found that chess masters are able to remember chess positions from actual master games much better than lower ranked players. However, this is not because masters have a greater information processing capacity. Their memory for random chess positions is no better than that of the amateur's (deGroot, 1966). Rather,

the master has acquired the symbols, (or 'chunks') that allow them to efficiently encode those types of positions that occur in master play. Similar findings have recently been reported by Shneiderman (1976) concerning the memory for sensible and randomized programs.

These findings imply that a theory of human communication cannot be based primarily on a notion of bits. However, analysing experiments in terms of bits did result in a useful finding; viz., that people can more easily discriminate and memorize signals when these signals differ in many rather than few dimensions (See section 3.5 below).

2. *The Encoding-Decoding Model*

In this section, a common model of communication will be presented. To facilitate discussion, this view will be referred to as the Encoding-Decoding or E-D model. (See Figure 1.) The E-D model basically views communication as follows: One communicator, a sender, has an idea (or information) in his head. The sender translates this internal structure into some external code (like a sentence) which is transmitted through some medium to the other communicator (called a receiver). This receiver decodes the message into the language of its internal states. Communication is considered 'good' or 'effective' to the extent that there is an isomorphism between the relevant internal states of the two communicators. This model is useful, under certain circumstances, for discussing 'communication' between two computers. It is detrimental to productive thought concerning communication between two humans. Further, it is insufficient for developing a natural language computer system. Yet, a perusal of recent summaries of work in this area indicates that scarcely any attention is given to considering the goals, or motives of the person who is to converse with a natural language system (See, e.g., Schank and Colby, 1973; Rustin, 1973). Nor are people typically concerned with the strategies of communication that humans use, though there are some exceptions (E.g., Collins, 1976). To some readers, the E-D view will seem to be a straw man. However, this view is not just a straw man model. Many people write as though the E-D model were true, and

design man-computer interfaces accordingly. This model is seldom explicitly stated in formal writing concerning communication. However, one may find reference to it (e.g., Simmons, 1973, pp. 65-67). Similarly, 'Basically, the view of language understanding expressed here is that there exists a conceptual base *into which* utterances in natural language are *mapped* during understanding.' (Schank, 1973, italics added). Sowa (In preparation) says, in effect, that Language is a means for communicating information from the speaker's brain to the listener's brain. For some reason, either to answer the listener's question, to get him to do something, or merely to impress him with erudition, the speaker wants to recreate in the listener's brain a mental model that is a replica of some model in his own brain....The study of language, therefore, is a study of how people convert a mental model into a string of words.

A more typical tactic is to mention briefly that (of course) goals are important and then proceed to ignore them. For example, Miller & Johnson-Laird (1976) state on page 122 'Second, a psychology of communication should characterize what people are doing when they use language.' And, on p. 123 'People talk to one another for a great variety of reasons.' Yet in their *extensive* 760 page book, *Language and Perception*, goals, game-theory, and strategy are nearly ignored. The fact that the E-D view is simple and nearly right part of the time makes it difficult to dispel. This paper argues that the E-D viewpoint is not the most useful one possible.

It is realized that if one's purpose is to build a natural language computer system, there are a large set of non-trivial problems to solve. One may be justified in ignoring certain problems (e.g., the game-theoretic aspects of communication) while concentrating *initially* on other problems (e.g., parsing, semantic networks). Thus, the above references should not be mistaken for criticism of the excellent work of those particular investigators. However, the E-D model has implicitly come to underlie the thinking of systems designers even in cases where it would be possible and useful to consider communication from the broader perspective presented in this paper. Typically, the goals of the person communicating with the system and

his strategies are apparently assumed to be unimportant or unknowable. Let us examine the assumptions of this model in more detail by contrasting these assumptions with those of the alternative view proposed in this paper.

2.1 *Pure cooperation*

First, the E-D model implicitly assumes the game-theoretic case of pure cooperation. There is no mention in this model of conflicting goals, of manipulation, of deceit, of diplomacy, or of teamwork.

—An alternative view of communication (the Design-Interpretation or D-I model) asserts that there are very few real occasions wherein the goals of two separate systems are in complete accord. Non-zero sum games, with partially conflicting goals, are nearly universally the case when humans converse.

2.2 *Encoding*

The E-D model assumes that the sender *encodes* some information he has in his head into a message; that is, translates from one symbol system to another. This idea of encoding begs several interesting questions about communication. For example, it ignores the issue of whether there are legitimate, even useful thoughts that cannot be expressed in language. It implicitly assumes that there is a kind of isomorphism between the idea or information in one's head and what one outputs in a language.

— The D-I model asserts that it is much more useful to view the process of the 'sender' as that of *designing* a message as a means to achieve certain goals. The relation of the message so constructed to what the sender believes to be true or knows to be true is extremely complex and variable.

2.3 *Transmission*

The E-D model assumes that the message is transmitted from the sender to the receiver through some medium that includes noise which may disturb the communication process. To some extent the detrimental effects of noise can be overcome by redundancy. In fact, much useful work has been done in terms of efficiency of coding schemes, error-correcting codes, information measures etc.

---The D-I model assumes that the effects of noise and redundancy depend upon the situation. For example, adding noise is not always bad, nor is adding redundancy necessarily good.

2.4 *Decoding*

•The E-D model assumes that the receiver *decodes* the message; that is, translates the message from some external language into internal codes.

---The D-I model assumes that a human 'receiver' is much less naive; that a message will be *interpreted* in the light of the receiver's knowledge of the world, including especially his knowledge of the goals of the sender.

2.5 *Isomorphism as a Measure of Successful Communication*

Finally, the E-D model assumes that the best measure of communication is in terms of the degree of isomorphism between the internal states of the sender and the receiver.

----The alternative D-I view is that 'successful' can only be defined in terms of the goals of a particular system, that only rarely are the goals of the two communicators identical, and that even in that special case, isomorphism is not only impossible, but not even necessarily desirable.

3. *Design-Interpretation Model of Communication*

The design-interpretation model views the communication process basically as follows. One person has one or more goals which he feels can be partially satisfied by communicating with another human. There are several ways that this can happen. The person may want to manipulate the second person into doing something. (E.g., make a request). The sender may himself want to be changed in a certain way and thus initiate communication so that he may, for example, gain from something the other person may say in return. (E.g., ask a question). Or, the sender may change his or her own internal state by *the process of designing* a message for output. (E.g., client-centered therapy). The external message is transmitted to the receiver. The receiver has his own goals to fulfill which will typically partially overlap with those of the sender. Based on his own goals, and his knowledge of the world, the receiver may change his internal state in some way.

The internal cognitive states discussed above may be expressed in any one of a number of formalisms (See, e.g., Anderson, 1976); however, the merits and deficits in the D-I model of communication are independent of any particular formalism. If one represents cognitive states as a semantic network, the encoding-decoding model essentially says that good communication will result to the extent that there exist an identical subgraph in the semantic network of the sender and receiver. The design-interpretation model of communication purports that as one strategy for fulfilling certain goals, one person designs a communication that he feels will produce, in the interpreter or in the designer, a semantic network with certain more useful properties than the current network. For a formal treatment that encompasses some of the notions of the D-I model, the reader is referred to Balachandran and Deshmukh (1976).

3.1 *Functional View of Communication.*

According to the D-I model of communication, the central type of analysis of communication is based upon an understanding of the functions of the communication. Unless an

understanding is reached of *function*, one will not be able to predict what effect changes in structures will have.

Let us examine a few examples. Suppose one wants to design a query language. Many have attempted to copy the structures of English so that the system will be easy to use. It is much more crucial however, to ensure that the query system supports all the *functions* that one uses when one wishes to query a data base. People can learn to use a variety of *structures* for expressing queries. Consider the novel ideas embodied in Query By Example (Zloof, 1975, 1977). The subject writes queries directly into a table. The system is quite easy to learn (Thomas and Gould, 1975) though the syntax is not that of a 'natural language'. Query By Example does allow the questioner to fulfill his goals with respect to querying a relational data base. This is a more important consideration than making the syntax (structure) of a language mirror the syntax of English.

As another example, consider naming conventions. One cannot predict the naming conventions that people will apply even to simple objects if one only considers the attributes of the objects to-be-named. Consideration must be given to the *goals* of a communicative act. If one is trying to design a message that will allow another to correctly choose one object from a set, the message will depend upon the attributes and values of the objects not to be chosen as well as upon those to be chosen (Olsen, 1970). Imagine, for example, that one is presented with an array consisting of a red triangle, a blue square, a blue circle, and a blue triangle. If one wanted to single out the blue circle, one could simply ask for the circle. However, if the blue circle were presented in an array that included a red circle, a green triangle, and a yellow triangle, a person could simply ask for the blue one.

It has also been observed that in answering questions, people do not simply translate a relevant subgraph of their semantic network; rather they answer a question based on a consideration of the current and desired states of knowledge of the questioner, as well as an

estimate of his linguistic and inferential abilities. Norman (1973) uses the example that a person asked where the Empire State Building is will answer quite differently if he is asked in Russia, Europe, or in New York City.

The following exchange, overheard on the campus of Case Institute of Technology, illustrates how one may consider the characteristics of the listener in designing an appropriate answer.

STUDENT ONE: What did you get on your Calc test?

STUDENT TWO: If you take my score and add 100 and divide by two, you get my score.

STUDENT ONE: (With no hesitation) Great!

Clearly, this question and answer are meant to communicate more than the *factual information* of the score. Similar considerations have been observed as applying to the understanding of requests (Clark & Lucy, 1975). People (in the right game-theoretic framework) respond to what they perceive they are wished to do, not according to what is said to them.

To illustrate further the importance of the functional view of communication, consider the use of grammar in language. Typically, one uses certain rules of grammar to the extent that one feels it will help achieve certain communication goals. In formal writing, or in trying to impress scientific peers, it is quite conceivable that one may use correct, though quite complex, grammatical constructions not because the particular structure chosen, or even a class of such structures, is the only syntactically acceptable way, but because it will produce the desired effect. In fact, the insistence on adherence to a *particular* set of rules of grammar in writing and formal speaking is sometimes used as a way of imposing obstacles to those who, because they were raised in a different linguistic community, must expend more effort in following these rules (See Farb, 1973, for examples). There be many slang expressions and even typographical errors which are in absolutely no danger of being misinterpreted. The insistence upon letter-perfectness is all right, but should be accepted for what it is — a strategy in a

game of power. People do not typically correct unimportant errors of grammar in the casual speech of their teachers, their bosses, or in the letters sent by journal editors. However, the converse case is perfectly acceptable. This fact is most easily understandable by taking a functional view of communication. Similarly, the exceptions to the above generalizations about errors are only understandable by considering the functional requirements that the designer of a communication has imposed upon his design.

In addition to grammatical rules that are *typically* (not always) followed, there are certain rhetorical rules. Some of these rhetorical rules are based on an understanding of what is most effective in terms of changing the cognitive structures of others. For example, a sentence that, well, in a word, rather finds its way in a manner not as quick as might be nor as smooth, is not actually grammatically incorrect, but rhetorically pointless (usually). A theory of communication that overlooks the functions of communication would not be able to distinguish the rhetorically anomalous sentence from the sensible one.

As mentioned earlier, many attempts to provide natural language computer systems seem unconcerned with an analysis of various goals a user of such a system may have. However, dialogues (Thomas, 1976b) collected under three different types of goals, though all concerned with order-handling and billing systems, exhibited quite different properties. For example, the frequency and type of conditional constructions varied depending upon whether the person was attempting to understand, to describe or to diagnose an invoicing system. Also, the types of questions that were asked differed. From this study and the ones cited above, it should be fairly clear that any human communication can only be understood with the consideration of the goals of communication.

3.2 Focus and Background

An important consideration of communication is that verbal communication, whether written or oral proceeds sequentially. A fact that interacts with this is that a person can only consider

a limited amount of detail at any one time. Together, these limitations make it very difficult to produce certain kinds of cognitive changes (e.g., the elimination of prejudice). This difficulty is best illustrated with the following example.

A man and his son were driving down the street one day when they were suddenly involved in a severe auto accident. The boy's father was killed instantly. The boy was seriously injured. Passersby called an ambulance which rushed the boy to the nearby hospital. They called the best surgeon for emergency surgery. The surgeon scrubbed for the operation, walked into the operating room and said --'Oh, my God, I can't operate --- that's my son!' Given that the father killed in the car accident was the boy's legal, biological father, and that the surgeon was telling the truth, how is this story possible?

The difficulty that most people experience when reading this story is that their conception of the story is not completely detailed with all the possibilities. Rather, at certain points in the story, 'default assumptions' are made (cf. Minsky, 1974). In particular, most people imagine that the surgeon is a man. Of course, there is no necessity that the surgeon is a man, and in fact, in this case, the surgeon is the boy's mother. If asked directly whether a surgeon can be a woman, people will almost invariably reply 'yes, do you think I am a male chauvinist?' --or words to that effect. People are perfectly capable of keeping that much cognitive complexity in mind. However, when the surgeon is just one aspect of a more complex story, most people will only instantiate the surgeon stereotypically with the concept MAN, rather than with the more complex idea MAN OR WOMAN. What makes this particular type of prejudice so insidious is that it is very difficult to change. When people are attempting to solve a fairly complex problem and the idea of surgeon is simply part of the background, their prejudice determines their choice of default value. However, when one points out the prejudice, the concept of surgeon becomes the *focus* of communication, and the person quite reasonably asserts that he (or she) is quite capable of thinking of a surgeon as a man OR a woman. Since, when the person examines closely his or her own cognitive structure they see no conflict

with reality (in reality, as well as in their cognitive structure, surgeons can be of either sex), the person is not motivated to change his concept of surgeon. Thus, the fact that language is sequential and the fact that there is a limit to the amount of detail one can perceive together make it very difficult to produce certain kinds of cognitive change.

3.3 Multiple Channels

Some investigators (e.g., Boyd & Wilson, 1974) have theorized that human communication occurs over several channels. Professionals who are effective in communicating (actors, salesmen, artists, musicians, politicians) often use not one, but *many* dimensions to produce cognitive change. When people are exposed to oral communication, they form impressions not only about the content of the message, but about the goals, emotional state, and personal characteristics of the authors of these communications. For example, Smith, Brown, Strang, Rencher (1975) found that subjects judged faster rate voices to belong to more competent people. Lass and Davis (1976) found that listeners could judge the height and weight of speakers more accurately than chance (even within sex). The same article references studies indicating that recorded speech conveys information concerning the sex, age, race, socio-economic status, personality, specific identify, and some facial features. A prime task for a complete theory of human communication is to analyse these factors, and determine the influence that they have on people's cognitive changes. This influence will, of course, depend upon the perceived situation as well as the individual's strategies for communicating. The point to keep in mind is that a communication does not simply change one's cognitions about the things ostensibly being discussed, but also may change one's cognitions concerning the speaker, his current state, and what sort of communication is likely to follow.

3.4 Relativity and Context in Communication

An important and often *desirable*, (though oft lamented) characteristic of natural language communication, is its imprecision. There are a variety of ways that natural language

can be imprecise-e.g., ambiguity and fuzziness. Ambiguity, though often a useful property (e.g., in diplomacy) will not be discussed here. A useful, formal way of dealing with fuzziness has been developed by Zadeh (1974). The purpose of this section, however, is to provide examples which illustrate the utility of this 'fuzziness', which I would prefer to characterize as 'relativity'. This property of natural language allows action taken on the basis of a message to incorporate information about (1) the receiver of the communication (2) the environment and (3) the remainder of the message.

Consider first the case of a writer who writes the following message: 'Joe was not afraid, for the man was neither tall nor strong.' Different readers of this message may differ considerably in their own height and strength. To a pro football linebacker, the man imagined may be only 6 feet tall and not able to press more than 150 pounds. A child may imagine a man only five feet tall and practically unable to move. What precise description could the writer have used to simultaneously allow varying readers to interpret his message in a manner enabling them to empathize with Joe's feelings?

Consider the following advice from a first aid book: 'If you must go outdoors into extremely cold air temperatures, particularly if high wind or humidity is also present, limit exposure time as much as possible' (American National Red Cross, 1973). Certainly, there are a number of vague qualifications in that statement. How cold is extremely cold? How high is a high wind or a high humidity? What does 'must' really mean? Or 'as much as possible'? Is this language used simply because the writers of the book believe that the readers would not understand a more technical set of guidelines? The D-I view of communication holds that the writing is as exact as it should be. How cold is cold depends upon too many factors, some of which are not knowable in advance, to specify exactly how long one should be exposed under what temperatures.

Polya (1957) tells us 'An inaccurate figure can occasionally suggest a false conclusion, but the danger is not great and we can protect ourselves from it by various means, especially by varying the figure.' Why does this mathematician, writing for mathematicians or at least students of mathematics not give us a probability? Much of our knowledge is in the form of guidelines. Writing is not inexact because of some flaw in natural language, but because it reflects accurately the level of our understanding. It would be misleading to the point of a lie to say 'The probability of an inaccurate figure suggesting a false conclusion is only .2544; furthermore, for every additional figure, this probability decreases by $.1 \times 1/(n^2)$.' Natural language statements are vague partly so that the interpreters of these statements may incorporate local conditions into actions.

Another advantage of natural language is that it allows a message to be interpreted relative to other parts of the message. It is certainly clear to philosophers of language that deictic terms such as 'this' and 'that' as well as indexical terms like pronouns depend upon context for reference (Alston, 1964). In addition, empirical work demonstrates that even the reference for concrete nouns depends upon context. The container for holding an apple is not the same as a container for coke (Anderson & Ortony, 1975). There is further evidence that one cannot adequately predict the probability of recall of a sentence on the basis of its deep structure components (Foss & Harwood, 1975) under the assumption that the components are independently retrieved. In other words, sentence recall seems to depend partly upon some configural or Gestalt properties of the sentence. Not only recall probability, but meaning itself depends upon Gestalt features of sentences. Consider the following example. 'An angry Muhammed Ali smashed his fist into the tall man.' What is the meaning of the verb 'smashed'? Certainly, the inferences that one might reasonably draw about the effects of 'smashed' are quite different from those in the sentence 'My angry baby boy smashed his fist into the tall man.' In one case, the tall man may respond with a lawsuit and in the other with a smile. Or, to take a less violent example, 'The sailor's first action after seven months at sea

was to buy a kiss from the beautiful blonde at the carnival.' We might imagine the act of kissing to be somewhat different from that referred to in the sentence 'To comfort her disconsolate daughter, the mother kissed her.'

Generally speaking, cognitive psychology, over the last ten years, has been forced into considering context effects as vitally important in many domains. Thus, for example, the perception of letters depends upon the words in which they are embedded (Wheeler, 1970). Free recall of words depends upon the list in which they occur (Tulving, 1966). Recognition (and transfer of learning) of a particular state in a problem depends upon how that state was reached (Thomas, 1974). The recognition of faces depends upon context (Watkins & Tulving, 1976). The social actions appropriate to an utterance depend upon the social framework in which the utterance occurs (Goffman, 1974). Natural language provides for such contextual interdependency of meaning.

3.5 *Metacomments*

One of the most important aspects of natural language communication is that it can be used not only to comment about the world, but also about the communication process itself. An earlier study (Thomas, 1976b) of dialogues in which a person was attempting to understand or describe a complex business system indicated that 1. it is important for a natural language system to deal effectively with metacomments and 2. though working in a specific domain (e.g., invoicing systems) limits the vocabulary for discussing the topics of conversation, it seems to do little to limit the vocabulary of metacomments.

3.5.1 Metaphor for metacomments. In considering the use of metacomments that people use, the following metaphor suggests itself. Imagine two runners who are proceeding along fairly parallel paths, but screened from each other's view. Since each is running over slightly different rough terrain, they must make unexpected maneuvers. Their payoff is closely tied to minimizing the distance function between them. They would like to have a way of signaling

each other. What sorts of signals would they like to be able to send in order to minimize the distance between them? The runners would want to be able to send messages relevant to their direction, their speed, and their internal state. An examination of dialogue transcripts reveals exactly these same categories of information provided by metacomments. People communicate not only about the topic under discussion, but also regarding direction of the conversation, speed of the conversation, and internal state of the conversers.

There are at least four different types of statements concerning direction. These may be thought of as *topic broadeners*, *topic narrowers*, *topic changers*, and *topic keepers*. An example of each of these respectively are: 'I don't understand the context for that comment.' 'Could we be more specific?' 'Now, let's discuss applications.' 'And, furthermore,....' Communicators may also make comments concerning the speed of the conversation, perhaps requesting a slow-down in pace ('Well, wait a minute now, I don't know. Perhaps...') or a speed-up (as in saying 'right, right, right' while the other speaker is talking.) Finally, communicators may communicate concerning internal states by attempting to motivate the other person (e.g., 'great!'), by attempting to influence another into believing something about their internal state (e.g., 'I'm tired.') or by telling the other to make an inference (e.g., 'therefore, it follows, ...') or not to make an inference that might reasonably be made (e.g., 'however,...').

According to the E-D view of communication, one might reasonably attempt a first approximation analysis of natural language, or build a working natural language computer interface that ignores metacomments. According to the D-I view though, one cannot understand natural language communication, nor will people be able to communicate effectively with a computer system that filters out metacomments. If one builds a computer system that does not handle metacomments, the metacomments will be need to be handled outside the system (e.g., feedback sheets that users fill out, education courses, telephone calls to the systems programmer, etc.). (This is not meant to imply that, with current understanding, handling these comments outside the computer system itself is a poor strategy).

In many computer systems, there are sporadic attempts to provide for some metacomments. Typically, these are added features. They include such items as a 'temperature-humidity index' that tells the user how busy the system is, an on-line query facility about what is available, a 'comments' command, or the ability to change 'topics' by always returning to an operating system. An alternative strategy to adding metacomment capabilities to computer systems piecemeal is to recognize from the beginning of systems design that the types of metacomments listed above are found in natural language communication for a reason, and that a computer *system* should also provide for these functions.

4. Applications to Man-Computer Interaction

4.1 Question-Answering Systems

It was mentioned earlier that humans both answer questions and respond to requests on the basis of perceived goals. Hopefully, computer-based question-answering systems will eventually involve at least a primitive level of pragmatic analysis. For example, suppose one queried a data base as follows 'Are there any PanAm planes that have been in operation continuously without inspection for four hours?' A typical query system (whether natural language or not) would probably respond 'NO' even in the case where there had been a plane in operation continuously without inspection for five hours. Arguably, the questioner should have stated his question in terms of a comparative. But even that would fail to produce the information that fifty planes had been in operation continuously for three hours and 55 minutes. Might it not be nice to have this information returned even though it was not specifically requested? Or, suppose that no planes were in operation at all. This might be very valuable information to the question-asker. One could imagine a system whose output of information would depend jointly upon what was asked and some preset evaluations of the relative importance of various kinds of departures from the norm.

By responding to a user's question with something *satisfying* rather than something that literally answers the question, several knotty problems of interpretation might also be avoided. As pointed out in Thomas (1976a) it is not really necessary for a system to carefully analyze the overt quantifiers in a request like 'Are all the houses on Easy Street over 50K?'. A useful response to that question as well as 'Are some of the houses on Easy Street over 50K?' and 'Are the houses on Easy Street usually 50K?' would be an easily readable summary of statistics concerning the maximum, minimum, median, mean price, and the percentage of over-50k-houses on Easy Street. This would probably satisfy the user and would avoid sticky problems of interpreting 'usually'. Obviously, deciding what would be the appropriate level of detail for particular applications would require study. But, this does not mean it is safe to simply ignore the fact that people want satisfaction, not just literal answers. Furthermore, a partial solution to the problems would provide incremental improvement to a system. It would not be necessary to guess perfectly what is 'really wanted' by the user every time; people are used to being misinterpreted --- but not to having no attempt made to answer their questions in a satisfying way.

4.2 Problem Solving Aids

Presumably, computer-based problem solving aids are contemplated because unaided human problem solving is often lacking in quality, quantity, speed, or enjoyment. These deficiencies may be impacted by training (Khatena, 1970) or by the use of non-computer aids (Thomas, Lyon, and Miller, 1977) but computer-based problem solving aids also hold great promise. The implications of the D-I view of communication to the design of complete problem solving aids are: 1. that the computer system should be able to acquire and make use of at least primitive information concerning the user's goals. 2. The system should be designed with a knowledge of *when* and *how* the system is trying to *persuade the problem solver to alter his or her behavior*. If the system will *not* alter the user's behavior, 'the system is

pointless. If it is to alter the user's behavior, the designer should be conscious of this fact and use persuasively effective means.

4.3 Editors and Command Languages

Recall that the relativity (or fuzziness) of natural language was useful in at least three ways. It allows for a message to be interpreted relative to the characteristics of (1) the receiver, (2) the environment, and (3) the rest of the message. In primitive form, these characteristics hold true for sophisticated editing and command systems which allow for (1) particular user-defined profiles and defaults, (2) commands whose interpretation depends upon the environment and (3) commands which take arguments or parameters. Extensive suggestions concerning these matters are given in Miller and Thomas (1976).

The realization that computers are a sophisticated tool to aid human communication leads one to consider issues outside the domain of narrowly defined man-computer interaction. For example, if a computer system is to be usable, then the persons who write instructions enabling humans to easily use the system should be responsible and rewardable for the quality of those instructions. The instructions *are an integral part* of the human-human communication system. They are not something added on which allows one to communicate with a machine.

Since goals largely determine behavior, if one is to improve the communication systems, of which computers are a central part, the single most important action is to ensure that the payoffs of those who design computer systems are directly related to their utility as tools of human communication.

4.4 Computer Systems.

A computer system should include facilities for the user to easily state or query changes in topic (or 'environment'). The facilities should make it easy for the user to signal that he or she wants to interact concerning a sub-environment, a superset environment or a totally different

environment. In addition, the system should be capable of providing the user with reassurance that he or she is in the assumed environment.

In principle, the system should also provide facilities so that the user and the system can signal a speed-up or slow-down in processing, although typically people want faster service than what is available. However, there is some evidence suggesting that unpredictable response time is more detrimental to user performance and satisfaction than slow response time (Miller, 1976; Thomas, 1977).

Finally, the user and system should be able to signal at least primitively concerning internal states. Again this exists now in primitive fashion. However, one could imagine a system that monitored the user's performance in certain tasks and suggested a coffee break when the error rate reached a certain point, or a system that would notice when a computer user was emotionally upset. Conversely, a computer system that crashes slowly and informs the user of its crumbling status would be desirable.

The point is not that none of these facilities exist; indeed, experience has apparently shown them to be necessary since many of them are often found as added features on computer systems. One gets the distinct impression however, that the primary design effort of most computer systems was not explicitly concerned with providing these functions.

5. Conclusions.

Investigators of language phenomena and computer systems designers surely realize that communication is more complex than encoding and decoding. Most would argue that they are fully aware that the E-D model is a simplification. However, in the course of attempting to solve complex problems of system design, the words 'encoding' and 'decoding' lead one to ignore important properties of communication. Using the words 'design' and 'interpretation' instead makes it more likely that important properties of the communication process will be

remembered and used in system design. These properties are 1. the game-theoretic situation is a primary determinant of communication; 2. it is more important to insure that a system include all the necessary functions of communication than that it mirrors common structures; 3. communication proceeds simultaneously on several fronts; 4. a concept which is, for the moment, in the background, may contain errors of oversimplification, even though when that same concept is made the focus of attention, the error may disappear; 5. the vagueness of natural language is sometimes good; 6. a system should provide for various categories of metacomments.

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Appendix A.

Details of the Set-relations Communication Experiment.

For each of forty set relations involving two sets, one of the two people knew the exact set relation. This was one of five types --- (A is a subset of B, vice versa, A and B were partially overlapping, A and B were identical, or A and B were disjoint.) Orthogonally, the other subject was given one of eight kinds of prior information. (A Venn diagram showing A as a subset of B, vice versa, A and B as identical, partially overlapping, or disjoint—or the English statement of the form 'All A are B', 'Some A are B', or no prior information). The subject with the exactly correct information was also told what information the other subject had. Pairs of subjects communicated under two conditions. In the cooperative condition, the subjects worked as a team. The person with the complete information sent a message to the other subject who was asked to draw a Venn diagram which unambiguously described the set relation between A and B. In the Competitive condition, the subjects communicated in the same way except that they were competing with each other. The subject with the complete information had to send a message to the other person that was correct (i.e., consistent with the actual set relation) and informative (i.e., limited the number of potential responses that the other subject could make). This message was allowed to be incomplete, ambiguous, or misleading, but falsehoods or irrelevancies were penalized.

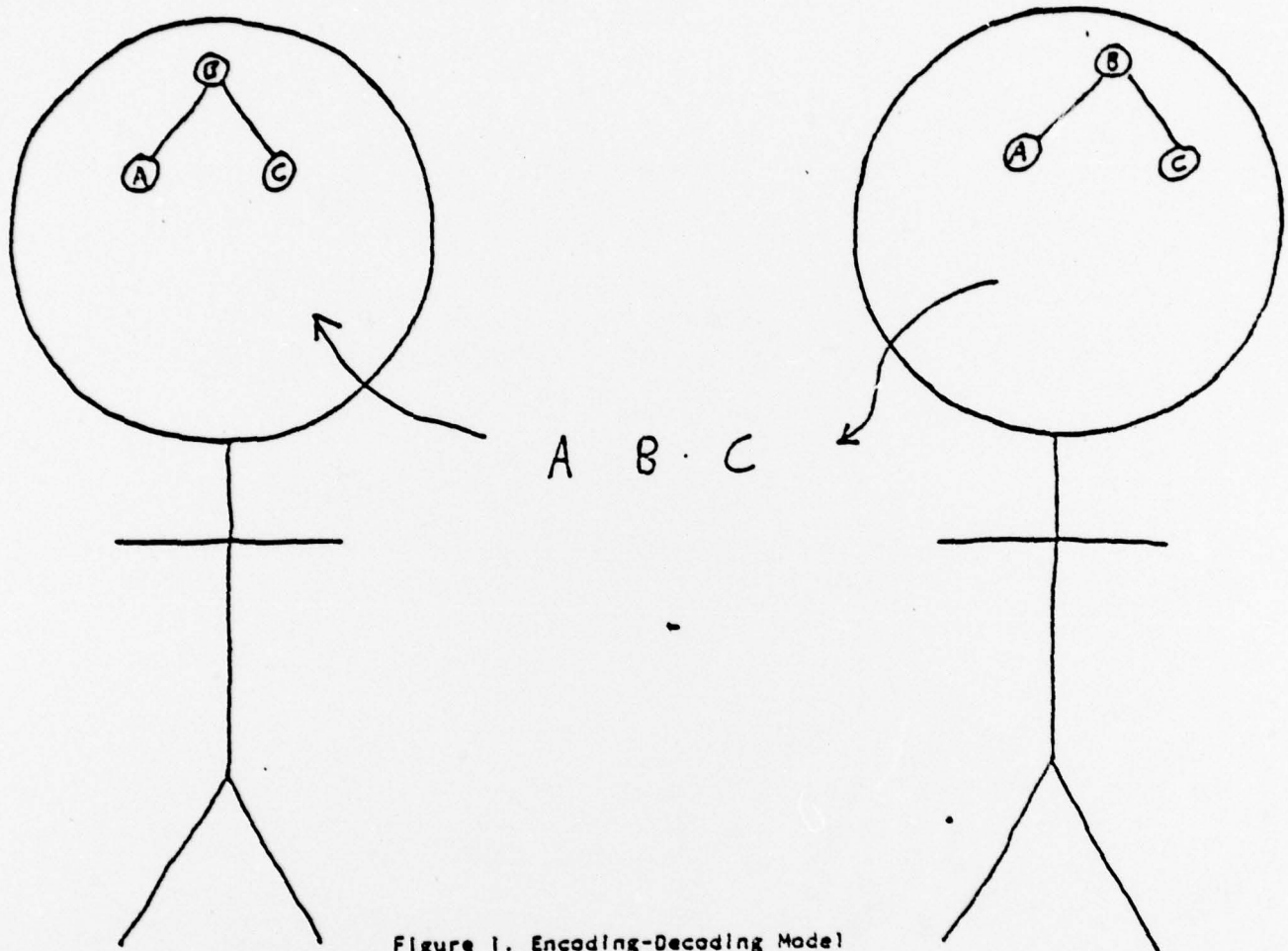


Figure 1. Encoding-Decoding Model

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