

On the Persistence of Beliefs

Kathleen Carley

Department of Social and Decision Sciences

Carnegie Mellon University

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Abstract

Beliefs are argued to form and change due to both social and cognitive considerations. A model of change in individual's beliefs as a function of both what objective information the individual learns and what they think other's believe is presented. The proposed model is contrasted with reinforcement theory and information processing theory and shown to fit a wider range of empirical studies than either of these alternative theories. The implication of the proposed model for the persistence of beliefs, including erroneous beliefs, are then examined. It is argued that individuals who hold erroneous or unsubstantiated beliefs can reinforce such beliefs in each other even to the extent that, despite evidence to the contrary, these incorrect beliefs will persist.

Keywords:

- Beliefs
- Attitudes
- Information
- Social Structure
- Communication

On the Persistence of Beliefs

People often persist to hold erroneous beliefs despite knowing contradictory evidence. For example, in the past few years people have begun not to give blood for fear that they might get AIDS. This particular belief is very resistant to change. Despite educational programs where people learn that you cannot get AIDS from sterilized needles and that in giving blood only sterilized needles are used people persist in this erroneous belief.

A variety of explanations can be offered for this and other similar phenomena. Many such explanations are predominantly cognitive in nature. For example, a comprehension argument "people don't understand the educational programs", or categorization-saliency argument "people keep information and beliefs separate, this for example, allows them to fight for the life of a calf one day and eat veal the next". are predominantly cognitive arguments that rely on a notion of limited cognition. Alternatively, psychological functionalist suggest that people hold attitudes or beliefs because they meet particular psychological (often emotional) needs (Katz, 1960; Herek, 1987) hence erroneous beliefs might be held because they reduce stress or increase feelings of self esteem. In contrast, a symbolic interactionists perspective suggests that the stability of social structures promotes a stability of self image and hence a resistance to change in beliefs, attitudes, and behaviors (Stryker, 1980; Stryker and Serpe, 1982; Serpe, 1987; Serpe, 1988). Attitude reinforcement theory suggests that erroneous beliefs persist only if they are extreme (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980; Hunter, Danes and Cohen, 1984). Information processing theories suggest that erroneous beliefs persist only if the most recent information supports an erroneous conclusion (Hovland and Pritzker, 1957; Anderson and Hovland, 1957; Anderson, 1959; Anderson, 1964; Anderson, 1971; Hunter, Danes and Cohen, 1984). And so on.

The idea that beliefs are a function of both individuals social positions and their mental models of the world is not new and indeed harkens back to ideas suggested by researchers such as William James, Cooley, Meade, and Festinger. However, formal mathematical treatments of this idea are rare. Mathematical

models of belief and attitude change are a-structural, that is, they do not consider the individuals social position. Many empirical studies tend to test only the predictions of the mathematically formulated models. Such empirical tests demonstrate the inadequacies of such a-structural formulations. In this paper, a mathematical model of beliefs as a function of both individuals social positions and their mental models of the world is developed. The proposed model then is contrasted with both reinforcement theory and information processing theory and shown to fit a wider range of data than these alternate theories. The implications of the proposed model for the persistence of beliefs then is examined.

The proposed model extends the constructural interaction-information exchange model proposed by Carley (1990) by incorporating a model of beliefs. The result is a partial-reinforcement model for individual's beliefs in which the level of reinforcement is affected by the order in which information is acquired. The extended model provides a more rich, detailed notion of self and has greater predictive capability. In addition, it can be used to examine how the concurrent development of beliefs by all individuals in the society determines the persistence of erroneous or correct beliefs at the social level.

In the constructural interaction-information exchange model, social and individual change and stability result from changes in the distribution of knowledge as individuals interact, acquire, and disseminate information. To this model, a model of beliefs is added in which a belief is a weighted sum of the relevant information the individual knows and what the individual thinks others believe. The resultant model thus combines aspects of both reinforcement theory (Fishbein and Ajzen, 1975; Hunter, Danes and Cohen, 1984) and information processing theory (Hovland and Pritzker, 1957; Anderson and Hovland, 1957; Anderson, 1959; Anderson, 1964; Anderson, 1971; Hunter, Danes and Cohen, 1984) with a structural perspective (Blau, 1977; Blau, 1974; White, 1976; Burt, 1982) in order to suggest that the concurrent exchange of information between individuals and the consequent change in individuals' beliefs, when beliefs are a function of both objective evidence and social pressure, can effect unwanted social consequences such

as the persistence of erroneous beliefs. Thus in the proposed model attitudes mediate one's interpersonal relationships through a process of "social adjustment" (Smith, Bruner, and White, 1956; Smith, 1973) and social structure (the initial social organization which dictates who will interact with whom) affects what attitudes the individual holds (Heider, 1946) as well as other behavior (White, 1976; Burt, 1982). To preview the results, since individuals acquire information (both "facts" and "others' beliefs") during interactions, if those with whom the individual interacts hold an erroneous belief the individual can become convinced of the erroneous belief despite the evidence and will in turn persuade others. Such "inadvertent" social pressure can lead to the persistence of an erroneous belief. This research suggests that even if there were no comprehension errors, no problems with categorization, no need for the belief, individuals, and as a result societies, may persist to hold erroneous beliefs in the face of contradictory evidence simply because "everybody believes such to be the case".

1. Social Agreement Model

Societies will be described in terms of the following primitives — people, groups, interaction, facts (objective information), and beliefs. Every group or society has a population; i.e., a certain number of individuals, denoted by I .¹ For every group there are a certain number of topics on which the members of the group have information and about which the members of the group might hold a belief or have an opinion or attitude.² Every group has a culture, which can be thought of as the distribution of information and beliefs across the population.³ At a particular point in time, say Time Period t , each individual in the group, such as individual i , has a certain probability to interact with each other member of the society, such as j given

¹All major symbols are defined in Appendix 1.

²The term belief is used to refer to a belief, attitude, conviction, or opinion and does not necessarily refer to a "religious" belief. As will be seen in the next section the individual's own belief is in the terminology used by Fishbein and Ajzen an attitude, whereas the degree to which an individual considers a fact or another's belief to be known are akin to their belief.

³This is an extension of (Carley, 1991) where culture was defined purely as the distribution of information and all information was treated as objective facts which were either known or not known.

that all members of the society are available for interaction, denoted by $P_{ij}(t)$. Every group has a social structure, which can be thought of as the distribution of these interaction probabilities across the population.

1.1. Beliefs

For simplicity of exposition, let us assume that there is only one topic. This topic can be thought of as a question such as "Can you get AIDS from giving blood?". Associated with this topic is a set of "objective facts or evidence" that is potentially "learnable" by the members of the group. Associated with this topic is a particular "truth" that is the conclusion or attitude that any individual who has access to all objective facts will reach if just the facts alone are evaluated. This topic is the object about which each individual at any point in time will have a belief that is informed by both those facts the individual currently knows and by what the individual currently thinks others believe. The individual's belief, however, may be different from the "truth" in which case we say that the individual's belief is erroneous.

The set of objective facts contains each fact that is known by at least one group member regardless of whether that fact pertains to the topic. The number of such facts will be denoted by K . At a particular point in time, say Time Period t , the individual i for any fact such as k , either knows that fact or does not. This is denoted by $KF_{ik}(t) = 1$ if the fact is known by individual i at Time Period t and 0 otherwise.⁴

Given all of these facts, and just these facts, there exists an underlying objective truth or conclusion that can be reached. As an epistemological point, if one imagined that the set of available facts changed over time then this "truth" could change over time. Thus, this paper does not represent an argument that there exists such a thing as a fundamental truth that is true for all time. Rather, the argument is simply that, at any point in time, there exists a body of evidence and given just this evidence there exists only one conclusion that is reachable from it. This objective truth, denoted by T , can be thought of as an answer to the question:

⁴The term KF corresponds to the term F as used in (Carley, 1991).

positive (yes you can get AIDS from giving blood), negative (no you cannot get AIDS from giving blood), or neutral (there is no objective truth — at this point in time it simply is not known whether you can get AIDS from giving blood).

Some facts support a positive conclusion and others a negative. This support is invariant and "objective"; that is, if a fact supports a positive conclusion it always supports a positive conclusion and all individuals see that fact as supporting a positive conclusion. For simplicity we will assume that there are no interaction effects between facts. Thus, each fact provides positive support or negative support and the objective truth is simply the sum of the support provided by the facts. The support provided by a fact is denoted by E_k and can take on values ranging from -1 to 1. A support of 0 indicates that the fact provides no support for a belief on this topic. Facts which do not pertain to the topic have a support of 0. The objective truth then is simply the sum of the support for it across all facts; i.e., $T = \sum_{k=1}^K E_k$. Whereas, for each individual the force of the evidence, denoted by $FE_i(t)$, depends on what facts he or she knows and is simply $FE_i(t) = \sum_{k=1}^K KF_{ik}(t)E_k(t)$.

Each individual has a belief, attitude, or opinion on this topic, denoted by $B_{ii}(t)$, that is a function of both what objective facts the individual knows at that time, and the individual's perception of social agreement. The individual's perception of social agreement depends on both what the individual thinks other's beliefs are and how many other people's beliefs the individual thinks he or she knows. Whether, at time t , individual i thinks he or she knows individual j 's belief is denoted by $KB_{ij}(t)$. Whereas, $B_{ij}(t)$ represents what individual i thinks individual j 's belief is at time t . The individual's perception of social agreement, represented by $SA_i(t)$, is based only on the sign of the individual's perception of other's beliefs and not the strength of those beliefs. Thus, individual i 's perception of social agreement is defined as: $SA_i(t) = \sum_{j=1, j \neq i}^I KB_{ij}(t)sgn(B_{ij}(t))$.⁵ Given this notation, the individual's belief can be represented simply as the sum of the force of the evidence and the level of social agreement that he or she perceives:

⁵The symbol sgn represents the mathematical function signum which has the property that $sgn(a)=1$ if $a>0$, $sgn(a)=-1$ if $a<0$, and $sgn(a)=0$ if $a=0$.

$$B_{ii}(t) = FE_i(t) + SA_i(t) = \sum_{k=1}^K KF_{ik}(t)E_k + \sum_{j=1, j \neq i}^I KB_{ij}(t)sgn(B_{ij}(t)). \quad (1)$$

Like the "truth" an individual's belief can be positive, negative, or neutral (no opinion). We can think of that part of the individual's belief that is due to the objective facts (*FE*) as being informed by knowledge and that part that is due to the individual's perception of social agreement (*SA*) as being due to social pressure. The term $KF_{ik}(t)$ can be interpreted as the probability that the individual *i* believes the attribute *k* to be relevant to the topic. Interpreted in this way, the proposed model in which the individual's belief is a function of both the evidence and perceived social agreement is essentially an argument that beliefs are not always based on a rational evaluation of the evidence or the individual's underlying beliefs about the applicability of that evidence (Liska, 1984) and that the departure from rationality is due, at least in part, to social pressure. Numerous studies have provided evidence that social pressure, in terms of what the individual thinks others believe and normative considerations, affects individual's attitudes (Molm, 1978; Humphrey et.al., 1988, for example).

This model of beliefs combines elements of both reinforcement theory (beliefs change in the direction of the new information) and information processing theory (there are limitations on the impact that information can have and recent information can outweigh older information). Thus an individual's belief or opinion on a topic will change over time as he or she acquires more information, either objective facts or subjective information on other's beliefs. Even after individuals know all of the objective facts they may change their opinion if the people they interact with hold a different opinion. Based on these formulations a series of definitions about the correctness of the individual's belief can be provided (Table 1). Specifically: individuals beliefs are correct if they match the "truth"; individuals beliefs are erroneous if they are nonzero and they are the opposite of the "truth"; and individuals beliefs are unsubstantiated if they are nonzero and the truth is zero.

***** Place Table 1 About Here *****

1.2. Interaction/Knowledge Cycle

Each individual therefore has a variety of information — facts, his or her own belief, and what he or she thinks other's believe — any of which can be communicated when the individual interacts. The constructuralist perspective (Carley, 1991) posits that there exists an interaction/knowledge cycle such that interaction leads to shared knowledge and that relative shared knowledge leads to interaction. In this paper, the constructuralist perspective is extended by noting that this "knowledge" is comprised of both facts and beliefs which effect the level of sharing and the resultant interaction somewhat differently.

Let us first consider the proposition that interaction leads to shared knowledge. It is generally demonstrable that individuals acquire information (and hence may come to share knowledge) during interactions. In order to represent this process a variety of simplifying assumptions are made. First, facts are presumed to be entirely unstructured. Since facts are unstructured knowing a particular fact does not apriori prevent or encourage the acquisition of specific other facts nor are some facts subsets of or consequences of others. Second, the individual can know contradictory facts. Contradictory facts are treated as "different facts" with opposite weights. Consequently the overlap in what facts two individuals know is just the sum of the facts they both know. Third, an individual has only one belief on a topic at a time. In other words, the individual cannot hold contradictory beliefs. Fourth, when two individuals interact each communicates one piece of information to the other. Fifth, individuals can only communicate information that they know. Sixth, all pieces of information known by the individual, both facts and beliefs (except for his or her belief about his partner's belief), are equally likely to be communicated. The term "beliefs" will be used to refer to both what the individual believes and what he or she thinks others believe. Individuals can communicate objective facts, their own belief, or what they think others believe. And finally, individuals always learn the piece of information that is communicated to them.

A specific piece of information, fact or belief, is communicated from one individual to another if the two individuals interact and if that is the piece of

information the communicator chooses to communicate. Whether individuals i and j interact at Time Period t is denoted by $INT_{ij}(t)$ where $INT_{ij}(t) = 1$ if they interact and 0 otherwise. All pieces of information known by the individual, facts and beliefs, are equally likely to be communicated thus if individuals know more facts than beliefs they are more likely to communicate facts, and if they know more beliefs than facts they are more likely to communicate beliefs. Let us now consider the communication of facts and beliefs separately.

Whether individual j chooses to communicate the fact k at Time Period t is denoted by $u_{jk}(t)$ which represents the random selection of a fact from all facts known by the individual such that $u_{jk}(t) = 1$ if k is the fact chosen to be communicated and 0 otherwise. The function $u_{jk}(t)$ represents the random choice of a fact k by individual j from the set of facts known by j , such that all pieces of information known by j are equally likely to be chosen. There are many ways in which this could be implemented. (See Carley (1990) appendix 2 for additional implementation details.)

Whether individual j actually communicates the fact k to individual i at Time Period t , denoted by $CF_{jik}(t)$, depends on whether individuals i and j interact and whether j chooses to communicate fact k . Thus,

$$CF_{jik}(t) = INT_{ij}(t) u_{jk}(t) = \begin{cases} 0 & \text{if } j \text{ does not communicate } k \text{ to } i. \\ 1 & \text{if } j \text{ does communicate } k \text{ to } i \end{cases} \quad (2)$$

An individual will know a fact the next Time Period if he or she knows that fact already or if anyone in the society communicates it to him or her. This is represented as:⁶

$$KF_{ik}(t+1) = KF_{ik}(t) \vee CF_{1ik}(t) \vee CF_{2ik}(t) \vee \dots \vee CF_{lik}(t). \quad (3)$$

In this model there is no forgetting; i.e., once an individual knows a fact he always knows it. And, in this model there is no discovery; i.e., if the individual interacts with himself no change occurs in what he knows.

Alternatively, individual j may choose to communicate his or her belief or what he or she thinks another, other than the interaction partner, believes. Whether

⁶The symbol \vee stands for the "logical or".

individual j chooses to communicate his or her belief about h 's belief at Time Period t is denoted by $u2_{jh}(t)$ which represent the random selection of a belief to be communicated from the set of beliefs known by j and is 1 if the belief $B_{jh}(t)$ is the belief chosen to be communicated and 0 otherwise. The function $u2_{jh}(t)$ represents the random choice of belief B_{jh} by individual j from the set of beliefs known by j , such that all pieces of information known by j are equally likely to be chosen. There are many ways in which this could be implemented. (See appendix 2 for additional implementation details.)

Whether individual j actually communicates the belief $B_{jh}(t)$ to individual i at Time Period t is denoted by $CB_{jih}(t)$. Thus,

$$CB_{jih}(t) = INT_{ij}(t) u2_{jh}(t) = \begin{cases} 0 & \text{if } j \text{ does not communicate } B_{jh}(t) \text{ to } i \\ 1 & \text{if } j \text{ does communicate } B_{jh}(t) \text{ to } i \end{cases} \quad (4)$$

As with facts, an individual will know someone's belief the next Time Period if he or she knows that belief already or if anyone in the society communicates it to him or her. This is represented as:⁷

$$KB_{ih}(t+1) = KB_{ih}(t) \vee CB_{1ih}(t) \vee CB_{2ih}(t) \vee \dots \vee CB_{jih}(t) . \quad (5)$$

Unlike facts, which are either known or unknown and whose evidence does not depend on who knows them or when they are learned beliefs can take on values, positive or negative, and may oscillate. Thus, over time individuals may change their belief on a topic and may change what they think others believe. The individual will always make use of what he or she thinks is the most recent information. Thus, even if the individual i already thinks he or she knows another individual's belief (such as h 's) individual i will change what he or she thinks h believes if he receives new information on h 's belief regardless of who provided the information. Thus:

$$B_{ih}(t+1) = \begin{cases} B_{ih}(t) & \text{if no one communicates } h\text{'s belief, i.e. } CB_{jih} = 0 \text{ for all } h \\ B_{jh}(t) & \text{if } j \text{ communicates } h\text{'s belief, i.e. } CB_{jih} = 1 \end{cases} \quad (6)$$

In this model the individual cannot "discover" another's belief but must learn it through interaction. Equation (6) pertains only to the individual's knowledge of

⁷The symbol \vee stands for the "logical or".

other's beliefs. The individual changes his own belief using Equation (1) after each interaction where he or she learns another fact or someone's belief.

Now let us consider the second structural proposition that the more similar two individuals are, relative to everyone else, the more likely they are to interact. What this amounts to is the suggestion that individuals are more "comfortable" interacting with someone with whom they have more in common, and that individuals "determine" how much they have in common with another on the basis of the social similarity the individual perceives between himself or herself and every other individual in the group. There are two aspects to this similarity — sharing objective facts and thinking that they share the same belief. The number of facts that two individual's share, denoted by $SF_{ij}(t)$, is simply the number of facts that they both know:

$$SF_{ij}(t) = \sum_{k=1}^K KF_{ik}(t) \wedge KF_{jk}(t) . \quad (7)$$

Whether two individuals have a shared belief (i.e., whether they agree or not) denoted by $SB_{ij}(t)$ depends on who you ask. Thus, from individual i 's perspective he or she shares a belief with individual j just in case i thinks that j 's belief is the same direction as his or her own. That is: $SB_{ij}(t) = 1$ if $sgn(B_{ii}(t)) = sgn(B_{jj}(t))$, $SB_{ij}(t) = -1$ if $sgn(B_{ii}(t)) \times sgn(B_{jj}(t)) \neq 1$, and otherwise $SB_{ij}(t) = 0$.

Now, we can represent the proposition that individuals are more likely to interact the more similar they are relative to their similarity with everyone else as:

$$P_{ij}(t) = \frac{SF_{ij}(t) + SB_{ij}(t)}{\sum_{h=1}^I SF_{ih}(t) + SB_{ih}(t)} . \quad (8)$$

Thus the probability that individual i chooses to interact with individual j assuming the complete availability of all individuals in the society, denoted by $P_{ij}(t)$, is a function of how many facts i shares with j , how many facts i shares with everyone else including himself or herself, whether i thinks they have the same belief, and the number of others with whom i thinks he or she shares the belief. Under this model, all else held constant, individuals who think they share a belief will be more likely to interact than will those who think they hold opposite beliefs. And, those who don't

know if they share a belief, or don't have a belief will be somewhere in the middle. Or in other words, all else held constant, individuals prefer to interact with those with whom they share beliefs over all others, and they prefer to interact with someone whom they think holds no belief over those whom they think hold the opposite belief. In the ensuing analysis it will be assumed that all individuals in the same society will have at least two facts in common, e.g. the fact that they are members of that society and the fact that they are interested in the topic. Thus the interaction probability between any two individuals will always be positive.

During a particular Time Period whether two individuals actually do interact is determined by each of their probabilities to interact with the other, and whether or not either of them already is interacting with someone else or spending the time alone. The choice of an interaction partner, or spending time alone, occurs serially. In the model, an individual is chosen at random to start off the selection of interaction partners. Initially, all individuals are equally likely to be selected. Let us assume that i is the selected individual. Let $A_j(t)$ denote whether individual j is available for interaction such that $A_j(t)=0$ if j already is interacting and 1 otherwise. Then, whether individuals i and j interact during Time Period t is represented as:

$$INT_{ij}(t) = v_{ij}(P_{ij}(t), A_j(t)) = \begin{cases} 0 & \text{if } i \text{ does not select } j \text{ to interact with.} \\ 1 & \text{if } i \text{ selects } j \text{ to interact with} \end{cases} \quad (9)$$

The v function represents the random selection of an interaction partner j by individual i from the set of individuals in the society who are available for interacting as weighted by his or her probability of interacting with those individuals. There are many ways of implementing this selection of an interaction partner. (See Carley (1990) appendix 2 for additional implementation details.)

1.3. Comments on the Model

This model has several noteworthy features. During a particular Time Period, individuals can never be more likely to interact with someone else than themselves as they cannot share more facts or beliefs with others than with themselves. Interaction probabilities are not necessarily symmetric between a pair of potential interaction partners. For example, asymmetries can occur if one individual simply

knows more facts than the other, or if one of them is incorrect in his or her perception of the other's belief, or if they share different amounts of information with different people. And interestingly, the interaction/knowledge cycle does not necessarily lead to positive feedback, since it is possible for i and j to interact, increase their shared knowledge, and yet be less likely to interact in the future. For example, this can occur if the interaction leads the individuals to conclude that they share opposing beliefs.

A consequence of the assumption that to be members of the same society a pair of individuals must share at least two facts is that everyone will end up knowing all of the facts that anyone does and will end up thinking they know everyone's belief (of course they could be wrong). This follows, because, if two individuals have a nonzero probability of interacting (which is guaranteed if they share at least two facts) and all pieces of information known by the individual are equally likely to be communicated then the two individuals eventually will share all their information since even though their probability of interacting can decrease it can never go to zero. Consequently if all pairs of individuals have a nonzero probability of interacting everyone ends up knowing all of the facts known by anyone and some perception of everyone's belief.

The interaction/knowledge cycle portion of the model is based on three empirical generalizations: (a) interaction leads to knowledge acquisition (Festinger, L., D. Cartwright, K. Barber, J. Fleichl, J. Gottsdanker, A. Keyesen, and G. Leavitt, 1948; Festinger, 1950; Granovetter, 1974; Garfinkel, 1981; Carley, 1986; Carley, 1990a), (b) homophily, the tendency of frequent interactors (such as friends) to be similar (McPherson and Smith-Lovin, 1987, for review), and (c) social relativity, the tendency of individuals to evaluate and determine their actions on the basis of their own characteristics and their perceived similarity to others (referred to by Burt (1982, p.1-16) as a "normative" tendency) (Merton and Rossi, 1968; Merton, 1968; McGuire, 1969; Sherif, 1935; Asch, 1951; Festinger, Schachter, and Back, 1950; Festinger, 1954). The proposed model combines these three forces — interaction driven knowledge acquisition, homophily, and social relativity — into a single

mechanism. This mechanism ultimately produces social solidarity and cultural cohesion (uniform interaction and everyone knows everything that anyone does) but in the process of doing so moves the society through a series of stages in which groups become more and less cohesive (Carley, 1991), and conflict arises, is mitigated, arises, and so on (Carley, 1990b). These generalizations are discussed in (Carley, 1990b).

The social agreement model, differs from the "facts only" model used in (Carley, 1991; Carley, 1990b) in that individuals communicate beliefs as well as facts. The upshot, in terms of previous results, is that it takes longer for the society to reach this ultimate solidarity as the communication of beliefs takes time away from the communication of facts. And, it is possible to get into situations in which the members of the society cycle between positive and negative beliefs. In other words, there are cases where even once all the facts are known complete cultural cohesion is not known and individuals and groups oscillate in what they believe. It will be demonstrated, that although such oscillations may last an incredibly long time the probability of remaining oscillatory forever is zero.

2. Relation to Alternate Attitude Adjustment Models

In this section it will be demonstrated that constructural theory (on which the proposed model is based), reinforcement theory, and information processing theory make different predictions regarding the impact of new information on change in the individual's belief (i.e., attitude change) and change in the individual's attitude toward the person from whom the individual acquired that information (i.e., source change). The belief portion of the proposed model, Equation (1), is essentially a partial reinforcement model of attitude change in which the order in which the individual acquires information affects the level of reinforcement. As such, the proposed model is somewhat similar to both reinforcement models and information processing models . The analysis presented herein draws on the detailed comparison of reinforcement theories, information processing theories, social judgement theories, dissonance theories, and congruity theories provided by Hunter, Danes and Cohen (1984).

2.1. Belief Change

Both reinforcement theory and information processing theory argue that the individual sees a sequence of messages about a topic, each of which contains one or more pieces of information, and based on each new message adjusts his or her belief about the topic. These theories differ from each other, and the constructural theory used in this paper, in defining the adjustment individuals make in their belief given new information. A message, in the parlance used in this paper, is the information that the individual learns during an interaction (i.e., either a fact or someone's belief). Reinforcement theorists and information processing theorists generally do not distinguish between types of messages or information, nor do they postulate that different types of messages will affect the individual's attitude in different ways.

Reinforcement theorists argue that the change in belief caused by the message is in the direction of the message (Hunter, Danes and Cohen, 1984). Thus positive information leads to a more positive belief, negative information leads to a more negative belief, and neutral information has no effect (see Figure 1).⁸ The individual's belief at a particular time is simply a weighted sum of the messages that he or she has received.⁹

***** Place Figure 1 About Here *****

In order to illustrate further the major similarities and differences between reinforcement models and the proposed model this discussion will be restricted to a discussion of the general belief change model derived by Hunter, Danes, and Cohen (1984) from Fishbein and Ajzen's model of attitude formation. In Fishbein's model, the individual's attitude toward an object (denoted by A_i) is simply the sum of the attributes' value (denoted by a_k) times the individual's underlying belief that the object has that attribute (denoted by b_k); hence, for individual i this can be represented as:

⁸For a similar graphic comparison of still other theoretical approaches see Hunter, Danes and Cohen (1984) Figure 8.1 p. 119.

⁹Reinforcement theories differ in whether the weights are a function of the individual, the message, the particular attribute, or some combination of these.

$$A_i = \sum_{k=1}^N b_{ik} \times a_k \quad (10)$$

where N is the number of attributes. Fishbein and Ajzen, and researchers following in their footsteps, generally treat these attributes as objective facets of the object. A parallel can be drawn between Fishbein's model and that proposed herein: the number of attributes is the number of facts plus beliefs ($K+I$), the attitude on the object is the individual's belief on the topic (B_{ij}), the attribute's value is the evidential weight of the fact E_k or the individual's perception of the other's belief $B_{ij}(t)$, and the individual's underlying belief that the object has that attribute is whether or not the individual knows that fact or belief KF_{ik} or KB_{ij} . Substituting these equivalencies into Equation (10) it can be seen that Fishbein's model equates to the proposed model in which the variables are time independent. As can be seen, there are two major differences between Fishbein's model (Equation (10)) and the proposed model (Equation (1)): (1) as noted by Hunter, Danes, and Cohen (1984) Fishbein's model is static and Fishbein has not provided a mathematical formulation for how the various components change, and (2) it does not distinguish between types of messages thus being told a fact and being told someone's attitude have the same effect.

Hunter, Danes, and Cohen (1984) formulate Fishbein's model as a model of belief change by essentially stipulating that individuals' beliefs change as they receive new messages, each of which alters an underlying belief about the presence of an attribute for that object. Thus there is a gradual change in these underlying beliefs as new messages come in such that

$$\Delta b_{ik} = w(m)b_{ik}(m)(1-b_{ik}(m)) \quad (11)$$

where m represents the m 'th message and $w(m)$ the impact of the message on the k th underlying belief. According to reinforcement theory all individuals who receive the same message react in the same direction (Hunter, Danes and Cohen, 1984,p.11); therefore, the sign of $w(m)$ is not a function of the individual. Consequently if all individuals receive all messages, all individuals eventually will converge to the same set of underlying beliefs and hence the same final belief.

In order to ease the comparison of Fishbein's model with the information

processing model, that will be presented next, let us consider a reformulation in terms of the message received by the individual at time t , denoted by $m_i(t)$, and the weight that the individual places on that message, denoted by α_i . The weight α is Δb and lies between 0 and 1. If we keep to the convention that each message pertains to only one attribute and therefore affects only one belief, we can reformulate the reinforcement model as saying that the individual's belief changes in the direction of the incoming message, which can be represented as

$$\Delta B_{ii}(t) = \alpha_i(t)m_i(t) . \quad (12)$$

Consequently the individual's belief is simply a weighted sum of the incoming messages; i.e.,

$$B_{ii}(t) = B_{ii}(0) + \sum_{n=1}^t \alpha_i(n)m_i(n) \quad (13)$$

As is evident from an examination of Equation (13) reinforcement theory predicts that: (1) the incremental change in the belief depends on the order in which the messages are received; (2) the order in which the messages are received does not affect the sign of the final belief that is formed after all messages have been received; (3) beliefs become entrenched; i.e., the more messages the individual has received that agree, even if it is the same message repeated, the more contradictory messages required to change the belief; (4) the more extreme the belief the less the belief shift when the message is contradictory; (5) neutral messages will not cause a belief shift; and (6) belief shifts are in the direction of the message.

In contrast to reinforcement models, information processing models argue that the individual sees a sequence of messages and adjusts his or her belief in the direction of the discrepancy between the message and the current belief (Hunter, Danes and Cohen, 1984).¹⁰ Thus positive information may lead to a less positive belief if the message is less positive than the current belief (see Figure 1). In order to further illustrate the major similarities and differences between information processing models and the proposed model this discussion will be restricted to a

¹⁰Information processing theories differ in whether the weights which determine how far the individual shifts his or her belief are a linear or non-linear function of the individual, the message, or some combination of these. Unlike reinforcement theory, however, these weights are not functions of the individual's belief or the underlying beliefs.

discussion of the linear discrepancy model studied by Hovland, Pritzker, and Anderson (Hovland and Pritzker, 1957; Anderson, 1959; Anderson, 1964; Anderson, 1971).

Using the previous notation, the linear discrepancy model states simply that the individual's belief changes in the direction of the discrepancy between the incoming message and the current belief, which can be represented as

$$\Delta B_{ii}(t) = \alpha_i(m_i(t) - B_{ii}(t-1)) \quad (14)$$

where α is not a function of belief and lies between 0 and 1. Consequently the individual's belief a weighted average of the incoming messages and the original belief; i.e.,

$$B_{ii}(t) = (1 - \alpha_i)^t B_{ii}(0) + \sum_{n=1}^t (1 - \alpha_i)^{t-n} \alpha_i m_i(n) \quad (15)$$

As is evident from an examination of Equation (15) information processing theory predicts that (1) the incremental change in the belief is not affected by the order in which the messages are received; (2) the order in which the messages are received does affect the sign of the final belief that is formed after all messages have been received as more recent messages are given greater weight than earlier messages; (3) beliefs become entrenched but information saturates; i.e., the more messages the individual has received that agree the more contradictory messages required to change the belief than in the reinforcement model;¹¹ (4) the more extreme the belief the greater the attitude shift when the message is contradictory; (5) belief shifts are in the direction of the discrepancy between message and belief thus neutral messages can effect a belief shift; and (6) positive messages can lead to a negative belief shift and negative messages can lead to a positive belief shift.

Now let us consider the proposed model in these terms. The structural theory argues that the individual sees a sequence of messages (which can be either facts or beliefs) and adjusts his or her belief in the direction of the message but at a

¹¹Roberts and Maccoby (1973), who take an information processing approach, argue in addition that individuals with more information will be more able to develop counterarguments to the new message and so will exhibit less of a belief shift given the new message than will individuals with less information regardless of direction of the new message.

level that is dependent on what type of message it is. Thus positive facts lead to a more positive belief if they were not known by the individual already and positive beliefs lead to a more positive belief. Negative facts and beliefs have just the opposite effect. Neutral facts have no effect on the individual's belief. If the individual learns that another's belief is neutral but previously thought it was positive then the individual's belief shifts negative and vice-versa (see Figure 1). This shift in the individual's belief can be represented as

$$\Delta B_{ii}(t) = \alpha f_i(t) m f_i(t) + \alpha b_i(t) m b_i(t) \quad (16)$$

where αf is the probability that the message is a fact and the facts is new $(1-KF_{ik}(t))$, $m f$ is the message containing fact k and hence has the value E_k , αb is a complex function which if the message is a belief adds what the individual now thinks the other individual believes to the change in belief and subtracts what the individual previously thought the other individual believed. and $m b$ is the message containing belief j and hence has the value $B_{ij}(t)$. In other words, learning facts changes the individual's belief in the direction of the fact if the fact was not known already but the individual always relies on only his or her most recent information concerning other's beliefs. Using these same formalisms we can restate the constructural model of the individual's belief (Equation (1)) as

$$B_{ii}(t) = B_{ii}(0) + \sum_{n=1}^t \alpha f_i(n) m f_i(n) + \sum_{n=1}^t \alpha b_i(n) m b_i(n). \quad (17)$$

Thus, constructural theory combines elements of both reinforcement theory (movement in the direction of the message) and information processing theory (new information matters the most). As a result, the predictions made by the constructural theory are somewhat a mixture of the two alternate models. Specifically, constructural theory predicts: (1) the order in which the messages are received by the individual affects the incremental change in the individual's belief; (2) the order in which the messages are received affects the final belief that is formed after all messages have been received as more recent messages can replace earlier messages; (3) beliefs become entrenched; i.e., the more distinct messages the individual has received that agree the more contradictory messages required to change the belief; (4) the more extreme the belief the greater the belief shift when the message is contradictory; (5) neutral messages can lead to a belief change; (6)

belief shifts are in the direction of the message for non neutral messages, thus positive messages lead to positive or no shift and negative messages to negative or no shift.

A variety of empirical results exist that speak to these predictions. Table 2 provides a summary showing the relationship between the data and the predictions of reinforcement theory, information processing theory, and constructural theory. Unlike the other two theories, all of the predictions of constructural theory are supported by the data. That the order in which information is received affects both belief and incremental change in belief is fairly well established — see for example (Anderson, 1965; Hovland, 1957). Numerous studies have suggested that more established beliefs are more difficult to change (Cantril, 1946; Anderson and Hovland, 1957; Hovland, 1972; Danes, Hunter and Woelfel, 1984). In addition, Danes, Hunter, and Woelfel (1984, p. 216) in a study controlling for both the amount of information known by the individual already and the extremity of the belief found that "beliefs based on a large amount of information are more resistant to change" regardless of their level of extremity and extreme beliefs based on little information were less resistant to change than extreme beliefs based on much information. To the extent that extreme beliefs are also those for which the individual has the most information then extreme beliefs also would be resistant to change. A large number of studies (such as (Hunter, Danes and Cohen, 1984, ch10)) have found support for the discrepancy hypothesis of information processing theory (Whittaker, 1967; Insko, 1967; Kiesler, Collins, and Miller, 1969, contain reviews). A detailed analysis of these results, however, indicates that the data typically has the form shown in Figure 2. To summarize the results: (a) extreme beliefs, unless they are associated with more information, are generally more affected by contradictory information, (b) neutral messages may or may not lead to a belief change but if they do the change is typically that predicted by a discrepancy model, and (c) belief shifts are in the direction of the message for non-neutral messages. Thus these results provide basic support for the idea that there will be a negative correlation between belief shift and current belief regardless of message content predicted by information processing theory, but not for the idea that messages supporting an extreme belief will evoke a belief shift in the opposite direction.

2.2. Source Change

Most communication theories — reinforcement theory (Rosenberg, 1956; Fishbein, 1965; Fischbein and Ajzen, 1974; Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980), information processing theory (Hovland and Pritzker, 1957; Anderson and Hovland, 1957; Anderson, 1959; Anderson, 1964; Anderson, 1971), social judgment theory (Sherif and Hovland, 1961; Sherif, Sherif, and Nebergall, 1965), or any of the affective consistency theories such as dissonance theory (Newcomb, 1953; Festinger, 1957), balance theory (Heider, 1946; Heider, 1958), congruity theory (Osgood and Tannenbaum, 1955; Osgood, Succi, and Tannenbaum, 1957), and affect control theory (Heise, 1977; Heise, 1979; Heise, 1987) — argue that the individual who receives a message changes his attitude toward the source of the message as a function of the message (Hunter, Danes and Cohen, 1984, contains a review). Typically the arguments follow the line that messages have emotive content and so provide emotional support or punishment; thus the individual adjusts his or her attitude toward the source in order to enhance the level of support or to decrease the level of punishment, or because the individual agrees with the source or some combination of these. Regardless of the specific argument it follows from all of these theories that change in both belief and attitude toward the source: (1) should be systematically related, (2) will under most conditions be either positively or negatively correlated, and (3) change toward the source is a function only of the message, the individual's current belief, and the individual's current attitude toward the source. To illustrate these points we will consider the specific predictions of reinforcement theory and information processing theory.

Before doing so, however, let us consider the relationship among attitude toward source, interaction with source, and the incoming information. In the theories mentioned above, whether the individual interacts with the source is generally treated as an exogenous black box. In constructural theory a complete system is defined in which interaction with the source changes as the individual receives information from the source and as the individual receives information from

any other source. Attitude toward source, in structural theory, is thus reflected in the individual's probability of interacting with the source. Now, let us reformulate these alternate theories in the same way; that is, we will treat change in probability of interacting for these theories as a positive linear function of change in attitude toward the source. Thus, a positive change in attitude toward the source will be reflected in a positive change in the probability of interacting with the source. We will thus represent change toward source as ΔP_{ij} where individual j is the source.

According to reinforcement theory the individual's attitude toward the source will shift positively if the individual agrees with the source and will shift negatively if the individual disagrees with the source (Hunter, Danes and Cohen, 1984, p. 30) (see Figure 3).¹² Agreement or disagreement with the source is simply the individual's current belief times the newest message from the source. Thus, change toward the source can be represented simply as:

$$\Delta P_{ij} = \beta B_{ii}(t-1)m_{ij}(t) \quad (18)$$

where $m_{ij}(t)$ is the message received by individual i from individual j at time t and β is a constant denoting the impact of agreement on change in attitude toward source. Thus reinforcement theory predicts that: (1) source shift will be correlated with agreement, and (2) source shift will be systematically related to belief shift.

***** Place Figure 3 About Here *****

According to information processing theory the individual contrasts the message with his or her current belief and if the message is more positive than the current belief the individual shifts positively toward the source and if the message is more negative than the current belief the individual shifts away from the source (Hunter, Danes and Cohen, 1984, p. 50) (see Figure 3). Thus, change toward the source can be represented simply as:¹³

¹²For a similar graphic comparison of still other theoretical approaches see Hunter, Danes and Cohen (1984) Figure 8.2 p. 122.

¹³This formula is based on the simple shift model in which the individual attends only to the message. Alternatively m could be replaced by the $m_{ij}(t) - B_{ii}(t-1)$ with no impact on the results discussed herein.

Thus information processing theory predicts that: (1) source shift will not be correlated with agreement, and (2) source shift will be systematically related to belief shift.

In contrast to both reinforcement theory and information processing theory, and in deed to all other communication theories mentioned, constructural theory predicts that there is no guaranteed relationship between belief shift and source shift or source shift and agreement. According to constructural theory the individual's attitude toward the source will shift positively if new information makes the overall level of agreement between the individual and the source, relative to the individual and everyone else, greater than it was before and the source shift will be negative in the opposite case. Thus, regardless of whether the new information agrees or disagrees with the individual's current belief it is possible to get a postive, negative, or even no shift toward the source (see Figure 3). Constructural theory thus predicts that although source shift, current belief, and message content are mechanistically related, source shift cannot be predicted from current belief, message content, or agreement with the source without taking into account the shift caused by the message toward all possible alternate sources. Further, contrasting Figures 3 and 1 we see that both reinforcement theory and information processing theory predict a relationship between change in belief and change in attitude toward the source of the message whereas constructural theory does not.

Hunter, Danes, and Cohen (1984, p. 170) in a detailed study of both belief and source shifts found that "for the most part, source change is independent of whether or not the receiver and source agree or disagree about the object". Additionally, they report, what to them is a totally unexplainable phenomenon — "the most startling result is that source change and attitude change are almost completely independent." This latter finding, while consistent with constructural theory, is completely unexpected from the vantage of all other communication theories.

3. The Ultimate Distribution of Beliefs

Using the proposed model we will now examine a series of questions regarding the ultimate distribution of beliefs. In particular, the concern is with illuminating the conditions under which correct beliefs, erroneous beliefs, and unsubstantiated beliefs persist. In order to pursue this examination it is necessary to introduce the notion of a stable society. A stable society is defined as a society in which there is absolutely no change in who knows what or in who holds what belief. An individual is said to persist in a particular belief for as long as the individual's belief does not change. Thus, by definition, individuals who are members of stable societies will persist in their beliefs indefinitely.

3.1. The Persistence of Unsubstantiated Beliefs

In order to get a feel for the proposed model and its predictions regarding the ultimate behavior of the group let us consider a very simple case in which there are only two people and two facts which pertain to the belief. Recall that all individuals in the society concerned with the same belief are guaranteed to share two facts that do not pertain to the topic and thus their interaction probabilities are always positive. Thus the two facts referred to in the ensuing analysis are over and above these two non-topic facts. Given this simplification we can look at the equivalent Markov representation of the proposed model. In the Markov model each state is a complete specification of who knows what information (facts and beliefs) and holds what belief. Formulating the proposed model as a Markov model is instructive as it illustrates the ultimate relationship among interaction, social structure, facts, and beliefs.

In the two-person two-fact one-belief case you will always end up with a perfectly stable society. For the two-person two-fact one-belief society, the individuals eventually will end up sharing all the facts that either knows and holding the same belief. Which stable social configuration emerges (i.e., what belief is held) is determined by the initial distribution of facts across individuals. When there are only two facts that pertain to the topic the true belief will be neutral unless both facts agree. If both facts agree then both individuals, can only arrive at

the same belief regardless of what facts they know to begin with and the belief they arrive at must be the correct belief. A more interesting case arises if the facts disagree and the truth is neutral. In this case, although both individuals eventually must hold the same belief, that belief may be unsubstantiated. In the trivial cases where everyone starts out knowing everything both individuals always end up holding the correct (and in this case neutral) belief. In all other cases what belief persists in the end depends on the order in which information is exchanged.

To illustrate this, we consider the case where one of the individual's starts out knowing all of the facts and the other knows only one fact (see Figure 4 in which the initial state is state A). Hence, initially the individual who knows everything (individual 2) starts out with the correct belief (0) and the other individual begins with an unsubstantiated belief (1). The order in which the individual's exchange information determines the final distribution of beliefs. In other words — history matters. It is possible for an unsubstantiated belief to persist indefinitely simply because individuals exchange beliefs before facts that are "new" to their communication partner (this is illustrated by the movement from state A to B to E to F). In this path we see that the social pressure exerted by the first individual on the second in going from A to B caused the second individual to ignore the evidence and adopt an unsubstantiated belief. Once both individuals hold an unsubstantiated belief, and think that the other holds the same belief, that belief will persist indefinitely even if the individual who initially was missing certain factual evidence later learns those facts (as happens when you move from state E to F). It is possible also for the society to get into an oscillatory mode where first one individual holds an unsubstantiated belief and the other a neutral belief, and then they switch beliefs, back and forth over and over again (this is seen in the movement from state C to D and D to C).

***** Place Figure 4 About Here *****

Now let us consider the case where individuals begin by having opposing beliefs. In this case, eventually, the society will stabilize and both individuals will hold either a positive, negative, or neutral belief. Prior to such stabilization the

society may oscillate such that one individual holds a positive and the other a negative belief and then they switch or one individual holds a positive or negative belief and the other a neutral belief and then they switch.

3.2. Eventual Cultural Agreement

The proposed model is essentially a model of increasing social and cultural solidarity. According to this model, over time the individuals come to share more and more information, thus the culture becomes increasingly homogeneous, the level of interaction between all dyads equilibrates, all individuals come to share more equivalent social positions, and the social structure becomes increasingly homogeneous. This movement toward social and cultural homogeneity is, according to this model, a product of the continual construction of the individuals' identities as they interact and acquire information. What this means in terms of beliefs is that eventually, all individuals will end up sharing the same belief and thinking that all other individuals share the same belief. In other words, (1) there is always a stable state, (2) in this stable state all individuals share the same belief, and (3) depending on the history of the group this belief may be incorrect.

To prove that this is the case, it first will be demonstrated that there exists stable states where once they are reached no change will occur. Then it will be demonstrated that such stable states must be states of cultural cohesion where all individuals have the same belief and the correct perception of each other's belief. And finally it will be demonstrated that it is always possible to reach a stable state regardless of the initial cultural configuration.

First, since all pairs of individuals always have a nonzero probability of interaction all of the individuals eventually will know all of the facts and will think that they know everyone else's belief. Thus, for all individuals the forces of the evidence is the same and will remain the same; i.e., $FE_i(t) = FE$ for all i . If an individual tells his or her communication partner a fact, since the partner knows the fact already, such a communication has no impact on the partner's belief. Thus, once you get into a state where all individual's know all of the same facts the only

way to change states is to communicate beliefs. If there exists no individual who by communicating a belief can change someone else's belief then that society is stable. If an individual tells his or her communication partner someone's belief, e.g. that individual h believes "x", and the partner already thinks that individual h believes "x" then the communication will have no impact on the partner's belief. Therefore, individual i can have no impact on individual j 's belief just in case i and j share the same belief about everyone else's belief and j has the correct perception of i 's belief; i.e., if for all $h \neq j$, $B_{ih}(t) = B_{jh}(t)$. Therefore, a society is only stable if for all ij pairs, they share the same perception of everyone else's belief and j has the correct perception of i 's belief; i.e., for all ij $h \neq j$ $B_{ih}(t) = B_{jh}(t)$ and $B_{ii}(t) = B_{ji}(t)$. Thus, a stable state exists just in case all individual's have the same perception of everyone else's belief.

Second, it now will be shown, that a state only can be stable if there is cultural cohesion; i.e., if everyone has the same belief. Let $SA_{ix}(t)$ be the amount of social agreement perceived by i discounting his or her perception of j 's belief; i.e., $SA_{ix} = \sum_{h=1, h \neq i, j}^I sgn(B_{ih}(t))$. Then, we can restate i 's belief (Equation (belief)) as $B_{ii}(t) = FE + SA_{ix}(t) + sgn(B_{ij}(t))$. For all ij pairs if i is to have no impact on j then $SA_{ix}(t) = SA_{jx}(t) = SA(t)$ and $B_{ii}(t) = B_{ji}(t)$. Therefore for any pair of individuals it must be the case that $B_{ii}(t) = FE + SA(t) + sgn(B_{ij}(t))$ and $B_{jj}(t) = FE + SA(t) + sgn(B_{ji}(t))$. Now assume that i and j have different beliefs; i.e., $B_{ii}(t) \neq B_{jj}(t)$. There are two cases, that where i 's belief is not neutral ($B_{ii}(t) \neq 0$) and that where it is neutral ($B_{ii}(t) = 0$). If i 's belief is not neutral then $|FE + SA(t)| > 1$ and the $sgn(FE + SA(t)) = sgn(B_{ii}(t))$. If this is the case then $B_{jj}(t)$ must have the same sign as $B_{ii}(t)$. If the sign of i and j 's belief are the same then their beliefs must be identical. Therefore, if i 's belief is not neutral $B_{ii}(t) = B_{jj}(t)$. The second case, where i 's belief is neutral can occur in two ways. First, it can occur if $FE + SA(t) = 0$ and $B_{ij}(t) = 0$ in which case $B_{ii}(t) = B_{jj}(t) = 0$. Second it can occur if $FE + SA(t) = -1 \times sgn(B_{ij}(t))$. But, if $B_{ii}(t) = 0$ then $B_{jj}(t) = FE + SA(t)$. Therefore, if it is a stable state, for all ij pairs $B_{ii}(t) = B_{jj}(t)$. Since the state is not stable unless all pairs of individuals have identical perceptions of everyone else and the correct perceptions of each other, and since these conditions guarantee that the individuals have identical beliefs, the only stable state is one where all individuals have exactly the

same belief and think all others have this same belief. In other words, the only stable states are states of cultural cohesion.

The final step is to demonstrate that every society, regardless of its initial configuration eventually will reach a state of cultural cohesion. For any society you eventually will reach a state where all the individuals know all the facts and have a perception of all other's beliefs. From any state, there exists a historical path such that during each subsequent interaction only one pair of individuals interact, one of those individuals is always individual i , individual i always communicates someone's belief, and his or her partner always communicates a fact. This path can be ordered to guarantee that eventually all individuals share the same belief.

Assume that there exists an individual, i , such that $sgn(B_i(t)) = 1$, i thinks that there are n_1 people other than himself who have a belief whose sign is 1 (call this Group 1), n_2 people who have a belief whose sign is -1 (call this Group 2), and n_3 who have a neutral belief (call this group 3). In order to have this belief $FE+n_1-n_2$ must be greater than 0 (see Equation (1)). Now, let i interact with all members of group 3 and tell them what he thinks everyone else's belief is, including his (i 's) own. This will convert all members of group 3 to a belief whose sign is 1 because they will now all have the belief $FE+n_1+1-n_2$ which is greater than 1. Now, let i interact with all members of Group 2 and tell them what he thinks everyone else's belief is, including his (i 's) own. This will convert all members of Group 2 to a belief whose sign is 1 because they will now all have the belief $FE+n_1+1-n_2-1$ which is greater than 0. Now, let i interact with all members of Group 1 and tell them what he thinks everyone else's belief is, including his (i 's) own. This will convert all members of Group 1 to a belief whose sign is 1 because they will now all have the belief $FE+n_1-1+1-n_2$ which is greater than 0. After these communications all individuals now have the same belief. Now, let each individual, communicate with all other individuals telling them only their own belief. Since their beliefs are identical, communication of their own belief can only reinforce their partner's belief. After these communications are through all individuals will have the same belief and have the same perception of everyone else's belief; i.e., they will be in a stable state which

is culturally cohesive. If individual i 's belief had the sign -1 , a similar procedure could be followed.

Now consider the case when there is no individual who has a non-neutral belief such that $n_1 \neq n_2 - FE$ (otherwise the approach outlined above applies). In this case everyone's belief is neutral. This can only happen if either everyone thinks everyone else is neutral (in which case it is a stable state) or there exists an individual i who thinks that someone else, such as j has a non-neutral belief. In this latter case, j then tells i that his or her belief is neutral. After which i 's belief becomes non-neutral and the technique outlined above can be applied. Therefore, you will always get to a stable state.

Thus, erroneous beliefs will persist indefinitely just in case the society gets to a state where all individuals share an erroneous belief. Unsubstantiated beliefs will persist indefinitely just in case the society gets to a state where all individuals share an unsubstantiated belief. Even if everyone initially has the correct belief, a historical sequence of interactions can bring about an incorrect belief unless initially there is also cultural cohesion. Societies always will be opinionated; i.e., the only case where a neutral belief will persist indefinitely will be if it is the true belief and the right sequence of interactions led to everyone sharing that belief and perceiving all others to share that belief.

3.3. When Evidence Dominates

Now let us consider, the question "is there any socio-cultural configuration that guarantees that an erroneous belief cannot persist?". The answer is simple: if evidence dominates then all individuals eventually will hold the correct belief. Evidence dominates just in case the force of the evidence is greater than the number of people — 1. Assume that all individuals in the society hold an erroneous belief and think that all other individuals hold a belief of the same sign. Let the sign of the erroneous belief be denoted by S . Then, the level of social agreement perceived by each individual is $SA_i(t) = \sum_{j=1, j \neq i}^I S = S(I-1)$. Each individual's belief will be equal to $B_{ii}(t) = FE + S(I-1)$. Thus, if FE is greater than $I-1$ all individuals eventually must come to the correct decision.

4. Discussion

Beliefs are typically more complex than the model proposed herein suggests. A single affective dimension often is not sufficient to capture a true belief (Bagozzi and Burnkrant, 1979; Schlegel and DiTecco, 1982). Factual evidence is not necessarily additive. Some people's beliefs may be more important to the individual than others (Humphrey et.al., 1988). And so on. Were such complications added to the proposed model it would not change the fundamental result that individuals can persist in unsubstantiated or erroneous beliefs just in case the level of social pressure that they perceive is greater than the level of factual evidence that they perceive. What such complications might change would be the prediction that eventually all individuals will agree and reach the same belief. And certainly such complications would affect the ratio of people to facts needed to guarantee that evidence will dominate social pressure and the rate of convergence to all individuals sharing the same belief.

Both reinforcement theory (in particular the Fishbein Ajzen model) and information processing theory (in particular the linear discrepancy model) also suffer this same limitation. As was demonstrated, despite this limitation, the proposed model is useful; i.e., fits empirical data better than the competing theories and makes numerous alternate predictions. Of particular importance is the prediction that different types of messages will affect beliefs differently. This follows in part, because the proposed model is not a purely additive model; new beliefs do, after all, replace old beliefs. As such, the proposed model can be viewed as a first step toward capturing the complexity of beliefs that is actually observed.

5. Passive Beliefs and Social Context

The proposed model of beliefs can be thought of as a model of passive beliefs. That is, it is suggesting that in general, people merrily go on their way interacting exchanging information and in the process accumulating a belief which they will hold unless some external circumstance causes them to sit back, take stock of the evidence they have accumulated and rationally evaluate it to form a new attitude independent of what they think other's think. No claim is being made that people

cannot logically evaluate data. Rather, what is being suggested is that in general, most beliefs are not "well thought out" but are reflections of the accumulation of information that the individual has received. Thus, if the individual has accumulated more perceptions of other's beliefs than factual evidence the individual will tend to go along with the crowd unless forced to "think about it".

Consider the following illustrative example. A friend of mine was told as she was growing up by her mother, and indeed her entire extended family, not to swallow gum as it would stick to her ribs. In highschool my friend took biology and learned basic anatomy and ostensible learned that if you swallowed things there was no way they were going to literally stick to your ribs. Several years later I heard her telling her daughter not to swallow her gum as it would stick to her ribs. Teasingly, I remarked, "of course you know it won't really". My friend looked at me in shock, paused a moment, and then said "You know, now that I think about it — you're right — I wonder why Mom always told me ...". My friend, an intelligent young woman, had simply never bothered to evaluate the facts at her disposal and instead was sticking to the belief that she thought most of those around her believed.

This story, and the foregoing analysis, suggests that many beliefs are somewhat accidental; that is, they are the result of what information you happen to hear first and the degree to which you think others share that belief. Beliefs then, are as much a function of the social context as they are of evidence. The proposed model predicts that the same person, placed in different social groups, will evolve different beliefs. Or as argued by Molm (1978, p.350) in a study of womens' sex-role attitudes "different attitudes may be reinforced as a result of contact with different sets of associates".

Thus, an individual or a group of individuals can control social opinion by controlling the order in which individuals receive information, whom they receive information from, and by fostering the belief among the receivers that other's share the same belief. Social control does not require that information be hidden or that people be prevented from accessing information. Simply making topics taboo so that

people think they know each other's belief, and spend little time exchanging beliefs may be sufficient. Or to turn this argument on its head, educational programs designed to provide individuals with all the facts, such as those on AIDS and smoking, are not guaranteed to change peoples beliefs. This research suggests, that in general, if the individual first learns other's beliefs, and comes to the conclusion that there is widespread social agreement that such and such is the case, then repeated education to the contrary may not change the individual's belief unless it first changes the individual's perception of other's beliefs.

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Appendix 1: Symbol Definitions

Symbol	Definition	
I	Population	number of people in society
K	Topic Complexity	number of pieces of information (facts)
$K+I$	Cultural Complexity	number of pieces of information (facts + beliefs)
$KF_{ik}(t)$	Facts Known	whether individual i knows fact k at time t
$KB_{ih}(t)$	Beliefs Known	whether individual i thinks he knows individual h 's belief at time t
$E_k(t)$	Evidence	the support that fact k provides on the topic
$B_{ih}(t)$	Perceived Belief	what individual i thinks is individual h 's belief at time t
$SA_i(t)$	Perceived Social Agreement	what individual i thinks the level of social agreement is at time t
$FE_i(t)$	Force of Evidence	the cumulative support provided by the facts known by individual i at time t on that topic
$P_{ij}(t)$	Interaction Probability	probability that individual i chooses to interact with individual j at time t , assuming all individuals are available to interact. Collectively this is social structure.
$INT_{ij}(t)$	Actual Interaction	individual i interacts with individual j at time t
$CB_{jk}(t)$	Communication to individual i at time t	individual j communicates fact k
$CF_{jh}(t)$	Communication to individual i at time t	individual j communicates fact B_{jh}
$A_j(t)$	Interaction Availability	individual j is available for interaction at time t
$SF_{ij}(t)$	Shared Facts	the number of facts that individuals

		<i>i</i> and <i>j</i> share at time <i>t</i>
$SB_{ij}(t)$	Shared Belief	whether individuals <i>i</i> and <i>j</i> share the belief at time <i>t</i>
$m_i(t)$	Message	either a fact or a belief that is learned by individual <i>i</i> at time <i>t</i>
α_i	Weight of Message	
ΔB_{ii}	Belief Shift	change in individual <i>i</i> 's belief
ΔP_{ij}	Source Shift	change in individual <i>i</i> 's attitude toward the source of the message (individual <i>j</i>)

Appendix 2: Technical Details

This appendix contains details on functions which can be used to implement various decision points which represent discontinuities in the model. These are the choice of a fact or belief to be communicated and the choice of an interaction partner.

Choosing a Fact or Belief to be Communicated

Each Time Period the individual will choose to communicate either a fact or belief. This choice will be represented by $u3(t)$ which is 1 if a fact is to be communicated and a 0 if a belief is to be communicated. All facts and beliefs known by the individual are equally likely to be communicated thus the probability that $u3(t)=1$ is

$$\frac{\sum_{k=1}^K KF_{jk}(t)}{\sum_{k=1}^K KF_{jk}(t) + \sum_{h=1}^I KB_{jh}(t)}$$

Choosing a Belief to be Communicated

The $u2$ function ($u2_{jh}(t)$) represents the random selection of a belief $B_{jh}(t)$ by individual j to be communicated during Time Period t . This $u2$ function has the following properties: all beliefs known by j are equally likely to be chosen, and $u2(t)=0$ if the individual is not communicating a belief. One way in which to implement the $u2$ function is described below. Let $u2_{jh}(t)$ have the form $u2(a,x,b) \times (1-u3(t))$.

Let $u2_{jk}(t)$ have the form $u2(a,x,b) \times u3(t)$. Then the selection of a belief is done by first choosing a belief to communicate. Which of the beliefs known by the individual is chosen to be communicated can be represented as:

$$x = r1 \sum_{l=1}^K KB_{jl}(t) \tag{20}$$

where $r1$ is a random variable drawn from a uniform PDF between 0 and 1. The selected belief x is the x' th belief in the set of beliefs known by individual j . The x' th belief in the set of known beliefs is translated into the k' th belief in the set of all K beliefs by a and b . The variable a is the number of beliefs known by j whose index is less than k :

$$a = \sum_{j=1}^{k-1} KB_{j(t)} \quad (21)$$

The variable b is the number of beliefs known by j whose index is less than or equal to k :

$$b = \sum_{j=1}^k KB_{j(t)} \quad (22)$$

These variables (a and b) will differ by 1 if belief k is known by j , otherwise they will be equal. The u_2 function will generate a 1 if k is the x th known belief and 0 otherwise; i.e.,

$$u_2(a, x, b) = \begin{cases} 0 & \text{if } x < a \text{ or } x > b \text{ } k \text{ is not communicated.} \\ 1 & \text{if } a \leq x \leq b \text{ } k \text{ is communicated} \end{cases} \quad (23)$$

A different random variable, r_1 , is drawn each Time Period, and for each person.

For facts, the u function is identical to the u_2 function except it operates on facts instead of beliefs.

Table 1: Definitions of Correctness of Individual's Belief

Sign of Individual's Belief	Sign of Truth	Belief is
1	1	Correct
-1	-1	Correct
0	0	Correct
1	-1	Erroneous
-1	1	Erroneous
1	0	Unsubstantiated
-1	0	Unsubstantiated
0	1	No Belief
0	-1	No Belief

Table 2: Constructural Theory Provides the Best Fit to the Data

Empirical Result	Reinforcement	Information Processing	Constructural
Order in which message is received effects level of belief shift	yes	no	yes
Order in which message is received effects final belief	no	yes	yes
The greater the information known by the individual the less the belief shift	yes	yes	yes
Contradictory messages effect greatest belief shift for extreme messages	no	yes	yes
Neutral messages can lead to a discrepancy belief shift	no	yes	yes
Belief shifts are in the direction of message for non neutral messages	yes	no	yes
Source shifts are not correlated with agreement	no	yes	yes
Source shifts are not correlated with belief shifts	no	no	yes

Each statement corresponds to an empirical result. A yes indicates that the theory's prediction accords with the data.

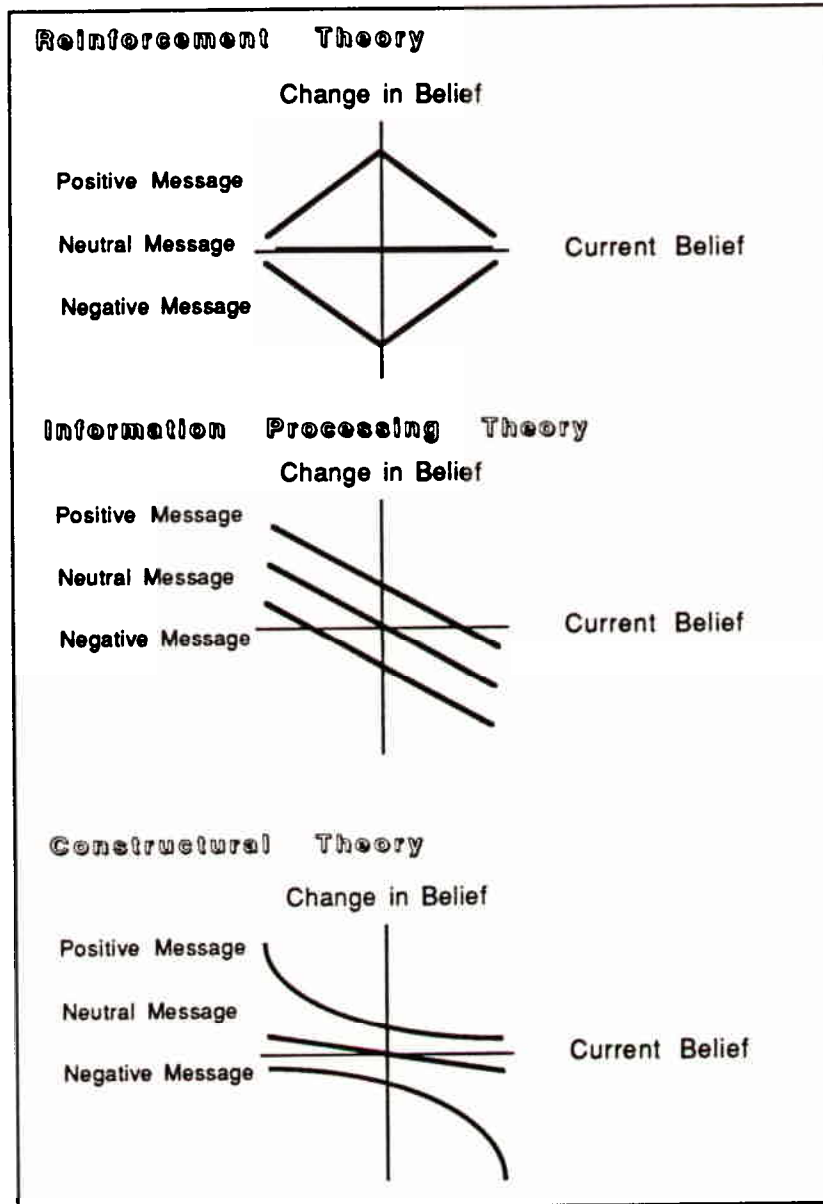


Figure 1: Comparison of Models Predictions for Belief Shift

Each graph represents the generic form of the curves predicted by that theory for the change in the individual's belief as a function of his or her current belief and the incoming message. The top line indicates the shift in belief given the current belief if the new information is positive. The bottom line indicates the shift in belief given the current belief if the new information is negative. The middle line indicates the shift in belief given the current belief if the new information is neutral. For information processing theory, middle graph, the intercept may shift depending on the individual's attitude toward the source. For constructural theory, bottom graph, the same generic curve is produced when the message is positive or negative regardless of whether the message is a fact or another individual's belief. For a neutral message, however, if the message is a fact there will be no effect and if the message is another individual's belief there will be an effect which depends on the difference between that new message and what the receiver previous thought the other individual believed

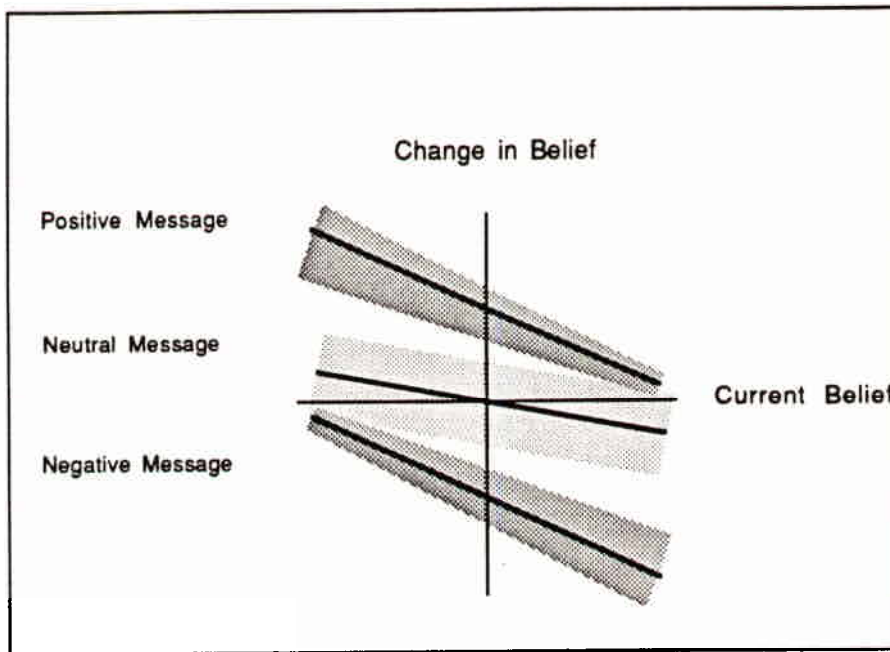


Figure 2: Typical Result of Belief Shift Studies

This graph represents the generic form of the curves found in studies of belief shifts as a function of message and current attitude. The top line indicates the belief shift given the current belief if the new information is positive. The middle line indicates the belief shift given the current belief if the new information is neutral. The bottom line indicates the belief shift given the current belief if the new information is negative. The shaded region around the lines is indicative of the level of variance in from this generic shape across the various studies.

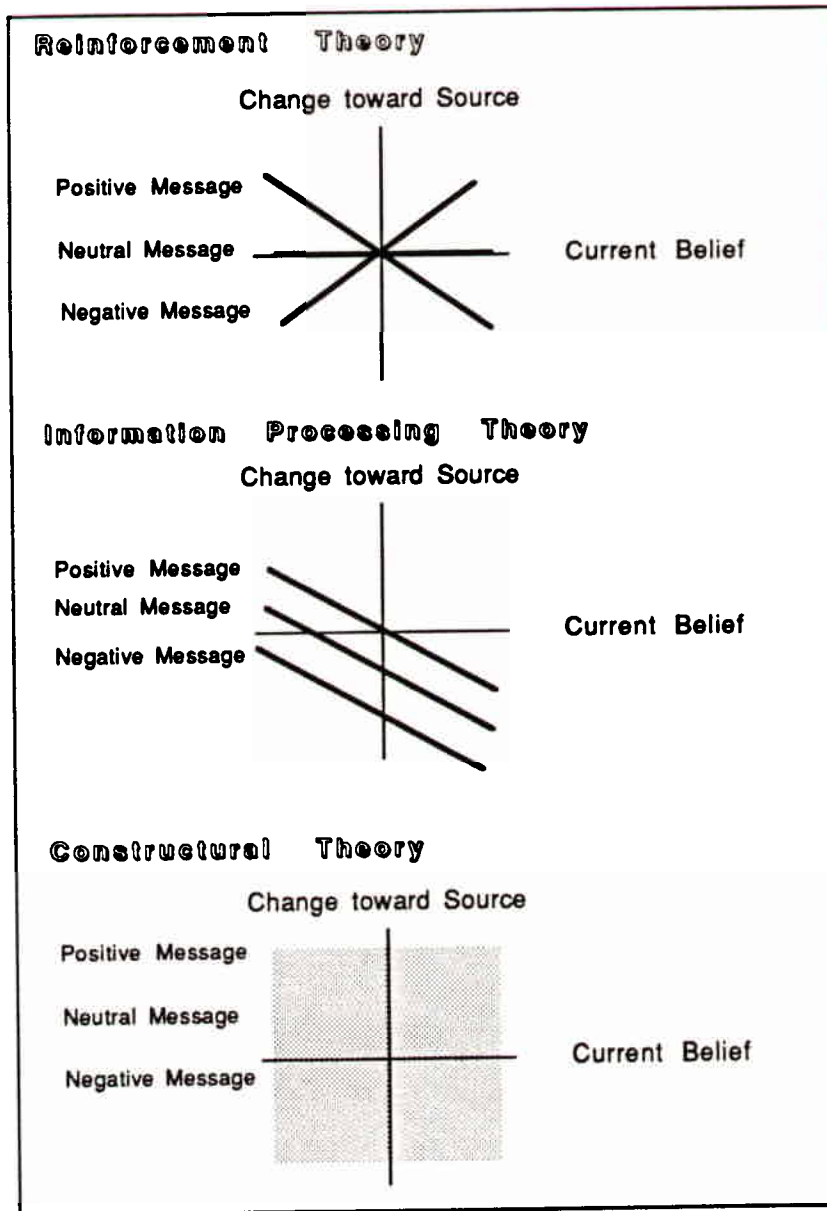


Figure 3: Comparison of Models Predictions for Source Shift

Each graph represents the generic form of the curves predicted by that theory for the change in the individual's probability of interacting with the source given the message as a function of his or her current belief and the incoming message. The individual's probability of interacting with the source is being treated as a function of the individual's attitude toward the source. The top line indicates the source shift given the current belief if the new information is positive. The bottom line indicates the source shift given the current belief if the new information is negative. The middle line indicates the source shift given the current belief if the new information is neutral. For reinforcement theory, top graph, the slope of the line changes with attitude toward source. For information processing theory, middle graph, the intercept changes with attitude toward source. For constructural theory, bottom graph, there are no lines as it cannot be predicted from just the the message and the current belief how the individual will change toward the source of the message.

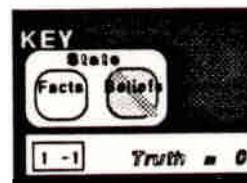
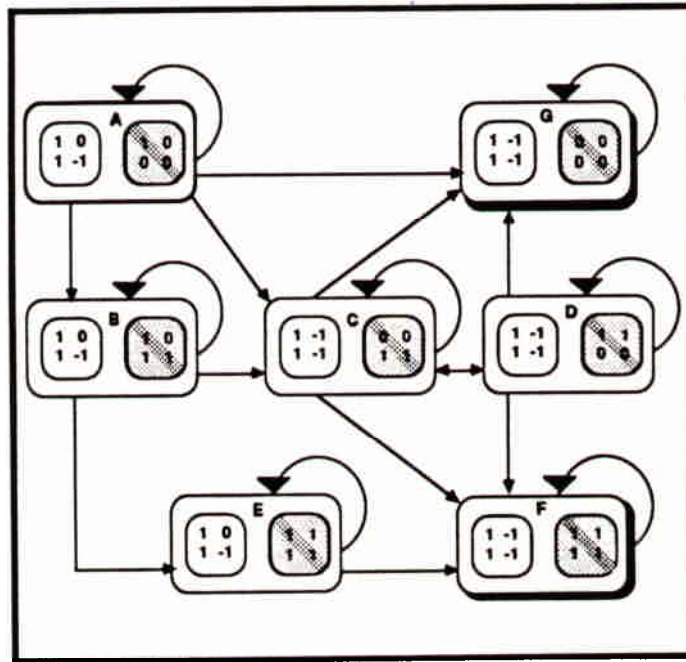


Figure 4: Unsubstantiated Beliefs May Persist Despite Evidence

This is a Markov representation of a society with two people and two facts that pertain to the belief. The two individuals also share two other facts, that do not pertain to the belief and are not represented here, whose effect on the process is to simply ensure that the probability of interaction never can be zero thus it is always possible to move along any of the arrows shown. Each possible social configuration (i.e., a state) is represented by a rounded rectangle which contains two smaller rounded rectangles. The small rounded rectangle on the left contains numbers that indicate who knows what facts; i.e., the rows are the people and the columns the facts. Facts are marked positive and negative to indicate whether they support a positive or a negative belief. The small rounded rectangle on the right contains numbers that indicates what the individual believes (along the diagonal), and what the individual thinks the other individual believes (off the diagonal). Thus state A is the society in which the first person knows the first fact and so holds a positive belief and the second person knows both facts and so holds a neutral belief. In state B the first individual has communicated his belief to the second individual who as a result of thinking that the first partner has a positive belief switches his or her belief to positive. There are two sink states, G and F, which are states where once you get there you can never leave and the society eventually will end in one or the other state. In G both individuals hold the correct belief which will now persist indefinitely. In F both individuals hold an unsubstantiated belief which will now persist indefinitely. It is possible for the society to get into an oscillation where the individuals hold different beliefs, learn each other's belief change their own belief, and then switch back again (this is seen in that one can go from state C to D and back again).