

Knowledge and the Development of Interpersonal Trust: a Dynamic Model

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Abstract

This paper presents a model of interpersonal trust dynamics, grounded in a longitudinal case study of an interorganizational information technology development project in New York State¹. System dynamics is the simulation method selected in this theory-building effort, based on qualitative data collected by the Center for Technology in Government. The model integrates concepts from economic models, as well as psychological and sociological theories about trust, learning, and perceptual processes in interpersonal relations. The simulation experiments show plausible path dependent behaviors with the characteristic asymmetries between trust and distrust described both in the literature and in the case data. The role of trust and knowledge development in the success of these projects will be explored by combining models of sub processes into larger models of the overall collaboration. The value of the model as a theory building tool will be enhanced by extended data collection and combining with related process models.

1. Introduction

This paper presents a model of interpersonal trust dynamics. The model is grounded in a longitudinal case study of an information technology development project involving state and local governments and nonprofit organizations in New York.² The case study produced observational and interview data about these interactions that indicated substantial growth in the levels of interpersonal trust among these participants. There was considerable evidence of feedback and learning as important factors in how trust developed over the course of the project. Therefore the case presented a potentially

valuable opportunity for theory development about trust and knowledge interactions in a dynamic environment. System dynamics is the vehicle for theory development.

Progress in theory development about trust can be particularly valuable. The development and maintenance of trust has been widely recognized as an important element in human relationships, whether at the interpersonal, group, or organizational level. As a result, substantial research attention has been directed to questions of what influences how trust develops or changes over time, how trust is related to social processes, and how trust links to organizational and interorganizational relationships. This research attention spans the full range of social science from economic models of transaction costs and negotiation, to sociological theories of group and interorganizational behavior, to psychological and culture-based models of interpersonal interactions. Despite the wide diversity in theory and focus of this body of research, however, there are some consistencies that led to the development of this paper. One is that the interpersonal aspects or factors of trust are central to almost all models, even though they model deals with group or organizational-level analysis. We conclude, therefore, that improving the understanding of interpersonal trust can contribute to many levels of analysis and bodies of theory. Another consistency is that trust is almost always treated as an implicitly or explicitly dynamic phenomenon, even when cross-sectional or static models are involved. These dynamic approaches to trust typically involve some form of learning or knowledge accumulation or change as important part of trust dynamics. Therefore the trust-knowledge linkage is a central part of the analysis of case data and modeling here.

2. Modeling trust in the interorganizational setting

The interorganizational collaboration involved in this case was a useful setting in which to examine trust and knowledge linkages. These linkages can be particularly important in interorganizational relationships, particularly

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when they involve the development of an innovation related to core missions or business processes. In such cases the risks of collaboration may be high due to the potential impacts of the innovation on organizational performance and individual jobs and status. The collaboration in this case was just such an effort, involving a new information system to be shared across many public and private organizations (the organizational setting is described in more detail below). The research group at the Center of Technology in Government (CTG) and the modeling group at the Rockefeller College began examining the collaborative processes in this case, resulting in an earlier dynamic modeling effort [1]. The model presented here is based on that work, but focuses primarily on the trust dynamics rather than the overall collaboration processes of the earlier paper. However both models are linked operationally through the interactions of trust with knowledge of a partner's role and objectives resulting from working together in a project.

The role of trust in interorganizational relationships is quite similar across most of the theory frameworks applied to how these relationships are structured and operate. In transaction cost analyses [2, 3] varying levels of trust, or the hazards resulting from untrustworthiness influence the structure of interorganizational relationships. Higher trust levels lead to lower costs resulting from the need to protect against opportunism. Political approaches and institutional analyses also have shown that trust is an important factor in governance mechanism across organizations [4-6]. But these structural approaches do not account for how trust develops.

Similarly, levels of trust influence the effectiveness of knowledge sharing and coordinated action in organizations processes [7], as well as teamwork [8], and collaboration [1, 9, 10]. In these as in the structural studies, however, trust is treated more as an influence on other phenomena than as the primary focus of attention.

In the large body of work on trust as the primary focus of attention, the wide agreement on its importance does not lead to similar agreement on the various forms, meanings, or causes of trust [11, 12]. There are, however, some important consistent themes and general understandings of the nature and dynamics of trust. Central elements in virtually all discussion of the nature of trust are the concepts of vulnerability, risk, and the role of positive expectations or optimistic belief [12]. In addition, the concepts of risk and expectations necessarily include some temporal dimension since both are prospective in focus. Similarly, without uncertainty and risk trust is not meaningful, and so is seen as accepting the risks associated with the type and degree of interdependence inherent in a given relationship [11]. One's vulnerability to or dependence on another party or

organization calls for trust when the trustee's behavior is not under the trustor's control [13].

The granting or withholding of trust between individuals is contingent on the expectation that the trustee will not behave opportunistically, especially when there are substantial incentives to do so [14]. Positive expectations or optimistic beliefs about the trustee are central [15, 16]. These expectations can be based on information and rational calculation, i.e., *calculus-based trust*. The information can be based in part on observation or learning from the trustee's past actions. However, the calculation may also depend on the trustor's ability to assess trustworthiness and *propensity to trust* [17]. Propensity to trust may be biased against easy trusting, or weighting distrustful behavior more heavily than trusting behavior in assessing trustworthiness [18]. Patterns of behavior over time matter as well. Paired set of partners have been observed to move successfully through a trial phase, during which risk taking increases as partners increase trust and move closer [19].

There is evidence, however, that these calculations can be influenced by both individual and organizational or institutional factors. Trust development can be influenced by the social or economic status or identity of the parties [18]. This *identity factor* in trust development can also be time related, resting on emotional or personal attachment developing through long-term reciprocal interaction [20]. Thus in any trust dynamic there is likely to be a wide range of factors influencing both the propensity of parties to behave in a trusting manner and the way the gather and interpret information about behavior and contingencies.

There is also a body of evidence that the trust development process has path-dependence properties [13]. The same research showed that it is very difficult to break distrust once the pattern of spiral reinforcement of distrust is formed. On the positive side, Larson's [19] work showed a reinforcing pattern of positive relationships. Trust has also facilitated the use of interorganizational electronic data interchange (EDI) by encouraging investment in information sharing and discouraging opportunistic behavior that would constrain the opportunity for greater information sharing [15].

3. The project context

This case study follows a project designed to develop a new management information system to be shared between the New York State Bureau of Housing Services (BHS) and state-supervised homeless shelter providers. The system, referred to as the Homelessness Information Management System, or HIMS, was intended to support management and evaluation of homeless client service programs. Funding from federal, state, and local government sources for programs for the homeless in New York State totals approximately \$350 million per

year, \$130 million of which is allocated to support services to clients.

The project setting is a mixed multi-government and private sector, interorganizational one. It consists of state, county, and city regulatory agencies and the nonprofit and local government service providers that receive financial support from the State. The State exercises supervisory responsibility over the shelter providers through BHS, which writes regulations that govern the physical, financial, and program requirements for shelters, certifies shelter programs according to these requirements, and conducts periodic inspections. 80 percent of the New York State homeless population resides in New York City, Westchester County, and Suffolk County. The New York City Department of Homeless Services (DHS) shares this regulatory responsibility for those providers that also receive City funding. Most shelter service providers are nonprofit organizations. They range in size from single facility operations that serve a few individuals or families at a time to multi-facility programs of large organizations like the American Red Cross. Outside New York City, the Westchester, Nassau, and Suffolk County social services agencies have similar roles vis-à-vis shelters and service programs.

Project activities were facilitated by the Center for Technology in Government (CTG). CTG receives funding from New York State to assist public agencies in information technology innovation projects. In this project CTG's role was to support and facilitate the collaboration among the participants, and to provide expertise and a development environment for the HIMS prototype, which was a central part of the project. Doing so focused attention on the issues of combining data from multiple existing case management and financial systems. CTG used group facilitation and decision-making support techniques to further support the progress of the project [21]. CTG staff was also engaged in case study research activities in parallel with the project facilitation. These included direct observation, interviews with participants, and review of project documents and other artifacts.

The collaborative nature of the project activities required participants from the state agency responsible for shelter oversight to work closely with managers from a wide range of homeless shelters in New York City, Westchester, and Suffolk counties. Over a 2-plus-year period, the project participants were able to achieve the necessary collaboration and share highly detailed and complex operational knowledge. The result was the design and development of a successful prototype shared information system [22].

The participants overcame several significant problems and barriers to collaboration. Implementing the HIMS had substantial threat potential for the shelter providers. The system could provide oversight agencies with enhanced ability to control or even eliminate programs or shelter

providers. Providers may also be in competition with each other for funding or clients, so sharing information could place them at a competitive disadvantage. Providers had to develop substantial trust in the oversight agencies and their colleagues to commit to building the proposed system and providing the necessary data. The model presented here represents the dynamics of how this collaboration and trust developed.

The need for trust extended to the technical and design issues in prototype development. Shelter providers do not have standard computing platforms, data definitions, or business practices. Designing a shared information system required the providers to share operational details about each other's business processes and to agree data definitions that were useful and valid across the provider population. Achieving this agreement often involved complex technical and organizational negotiations, knowledge sharing, and collaboration. Observing these processes over the course of the project provided the evidence of feedback and learning that is the basis for the dynamics in a formal model.

4. Methodological approaches in the study of trust

The methods used in this research, combining qualitative data collection and analysis with formal modeling, are unusual but not unique in social science research. The diversity of approaches used by social scientists in the processes of building or testing theories is extraordinary. In the attempt to get a better understanding of social phenomena, it is possible to use methods "ranging from deductive reasoning by rules of formal logic to efforts to understand and offer "thick" descriptions of the patterns of meanings and definitions of situations of people in everyday settings" [23].

The research on trust is not an exception, and it is possible to identify at least three main approaches in the study of trust. A first group of efforts follow a game theoretic approach mainly inspired in the work of Axelrod [24], who used the prisoner's dilemma to understand the dynamic nature of cooperation. This approach in the study of trust uses variations of the prisoner's dilemma calling them "trust games" [25-28]. A second group of researchers have tried to get a better understanding of the antecedents and outcomes of trust by the use of regression-like models [7, 29-32]. Finally, a third kind of effort focus in the discussion of the thick concepts associated with trust, reviewing and integrating explanations and interpretations, establishing a conceptual framework for the study of trust [11, 12, 17, 33, 34].

Each of the approaches has contributed to the conceptual and empirical understanding of trust and its role in social organizations. For example, game theoretic approaches have contributed to understand the role of

reciprocity and the expectation of future interactions in the development of trust. Statistical approaches to the study of trust, on the other hand, have contributed with the identification of the static structural characteristics of trust. Conceptual approaches offer rich descriptions, examples and counterexamples that provide alternative models and perspectives in the study of trust.

In spite of the quantity and quality of the efforts, researchers in the area still perceive a lack of a clear and concrete definition of the term itself [16, 17, 27, 30]. Some of the conceptual clarifications perceived as needed are related with the relationship of trust and risk, the mix of different levels of analysis, the failure to make a distinction between the party that trusts and the party to be trusted, and the distinction of trust as a matter of willingness to act or the act itself. Some authors call for the creation of models to describe and understand the dynamics and complexity of the phenomenon itself [35].

That is the strategy in this research, employing dynamic simulation to create a model or theory of trust formation. In order to elaborate a concrete theory of the development of trust over time, we have chosen to limit our modeling effort to the particular case of interpersonal trust. More specifically, the model presented in this paper describes the dynamics of trust development in a dyadic context where a person A (trustor) develops trust in a person B (trustee) with which he or she interacts on a regular basis.

5. Dynamic simulation and theory building

System dynamics is simulation method selected in this research, since it is well suited to both quantitative and qualitative-based research. Jay Forrester envisioned this modeling method in 1956. The premise is that dynamic behaviors (performance over time) are closely linked to an underlying structure of feedback loops. Articulating and understanding linkages between behavior and structure aids explanation of—and effective intervention in—dynamic, nonlinear processes arising from multiple interrelationships among aspects of a system [36].

As with grounded theory [37], a formal model is constructed by inferring from data and theoretical statements some hypotheses about causal relationships that generate a particular pattern of behavior over time observed in the field. Model-building proceeds by representing hypotheses with connected elements of model structure, simulating the structure, comparing the simulated behavior qualitatively and in degree to the behavior observed in the field, and returning to the observations and theories to refine the hypotheses represented in the model by changing its structure. In this sense, a formal model is a nontextual, mathematical expression of a theory of the cause-and-effect relationships that systematically produce the patterns of

behavior observed in the field [38]. The basic building blocks of the model are stocks (accumulations), rates (activities explaining how the stocks change) and feedback structures (closed causal relationships).

The mathematical nature of the method forces the analyst to be “quite exact and specific in attempting to specify causal dynamics that accomplish a satisfactory translation between verbal theory and empirical observations” [39]. Dynamic simulation helps to get a better understanding of verbal theories and any unexpected outcome obtained from them, with the potential to inform the activities of both, theorists and empirical analyst [40].

System dynamics has proven useful for studying complex feedback systems [40, 41]. Our present work extends initial explorations of trust and collaboration at the University at Albany [1, 22].

6. A formal model of trust

Given that the selected modeling technique assumes a close interaction between behavior over time and feedback structure, a dynamic characterization of trust requires both, a description of the behaviors observed and a causal structure that has the potential to reproduce those behaviors. The following sections describe these two key elements in the theory, accordingly to the data observed in the HIMS case and the literature on trust.

6.1. Trust characteristic behavior over time

Most of the research in trust refers to it as a dynamic phenomenon [42], in some cases comparing it with other perceptual processes involved in the interpersonal relationships [43]. As stated by some researchers [12, 27, 28] this dynamic characteristic is frequently associated, at least partially, with a series of reinforcing processes that characterize collaborative relationships. That is to say, collaboration provides an opportunity to trust, and through the accumulation of experiences, the persons involved in the process get to know each other to further develop trust, or to develop distrust [27].

Trust is also frequently characterized as a path dependent phenomenon [5, 12, 44]. Path dependence is a pattern of behavior that has not been fully explored. Its main characteristic is that “small, random events early in the history of a system determine the ultimate end state, even when all end states are equally likely at the beginning” [45].

The path dependent process involved in trust is more likely to be nonlinear according to the theoretical discussions and empirical observations. That is to say, researchers in the area perceive that the extreme values of trust or distrust are more likely to happen [12].

There is another asymmetry to take into account in the development of trust over time, namely differences between the process of building trust versus destroying it (creating distrust) [44, 46, 47]. Empirical and theoretical analyses of trust are consistent in pointing out that while building trust is a gradual process, it can be destroyed very quickly by single events or inconsistencies on the trustee's behavior. This observed asymmetry has led to some researchers to treat trust and distrust as two different constructs that can increase or decrease independently, moving in different continua [28, 48]. However, the modeling and simulation experiments described in this paper, suggest that the asymmetries can exist in a single continuum, considering distrust as the lack of trust, and not a different and conceptually independent construct.

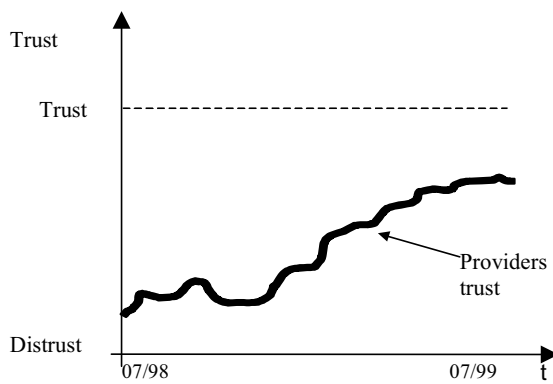


Figure 1. Providers' trust in the specifications stage of the HIMS project (*The graph was built in terms of CTG case descriptions [49] as well as the trust literature*).

The perceived qualitative behavior of the homeless providers' trust in BHS in the HIMS project is shown in Figure 1, which represents one realization of a path dependent process. Providers' trust started low mainly because of a previous experience with a case-reporting system (ANCHOR). The main providers' concern related with ANCHOR and later with HIMS was a high level of risk associated with the privacy rights of shelter clients. After several important actions from BHS to assure clients' privacy rights, providers' trust started growing. At the same time that they learned about the potential benefits of HIMS, however, they learned about some new risks associated to the existence of such a repository. For instance, they realized that the information gathered through the HIMS could be used to "publicly measure and report their performance as provider organizations" [49]. Based on their previous experience, they associated this possibility with the potential for BHS to use HIMS-based information for resource allocation purposes. As a result, BHS and the provider group started an effort towards the development of a shared framework for program and

service evaluation. Although learning about potential risks associated with the project promoted a temporal step down on the development of trust, the dynamics of the collaborative effort in the project promoted the reinforcing processes to work in favor of BHS, consolidating providers' trust development.

6.2. Trust feedback structure

In order to describe the structure of the model, the present section starts describing the general assumptions and mechanisms embedded in the model, and continues with a detailed description of the feedback structure in the model.

6.2.1. Model assumptions. As a basis for the overall approach to the modeling process it is useful to explore the conceptual structures behind the dynamic behavior of trust. Researchers in the area have identified several mechanisms of "trust production." In our review of the literature, we have identified four different processes or mechanisms associated to trust development: Institutional trust, calculative trust, knowledge-based trust, and identification-based trust.

Institutional trust refers to the existence of an institutional framework that regulates the relationship between the trustor and the trustee. This institutional framework can consist of laws, regulations or certification bodies that provide penalties for a party cheating in the interaction or provide certification of the trustworthiness of the trustee by a recognized third party. In any case, the existence of this mechanism to facilitate trust reduces the trustor's perception of risk in the interaction. Calculative trust refers to the trustee's estimation of the risks and pay-offs intertwined in the interaction. Changes in the perception of the institutional framework can result in changed perception of risk, promoting increases in the calculative trust. Knowledge-based trust is related to the ability of the trustor to assess the trustworthiness of the trustee. This assessment of trustworthiness can be based on the recognition of the expertise, the benevolence, ability, and integrity [17, 31], and it is associated with the history or the process of the relationship. Finally, identification-based trust is associated sometimes to emotional bonds, or with the existence of shared values or objectives between the actors.

Some researchers in the area consider that these different kinds of trust are not associated to different stages in the relationship [20]. Our perspective, however, is consistent with the one proposed by Rousseau [12], who considers that the calculative trust plays a more important role in early stages of the relationship. This changes towards a knowledge-based trust as the relationships matures, and the parties involved develop a

history of interactions and get to know each other (figure 2).

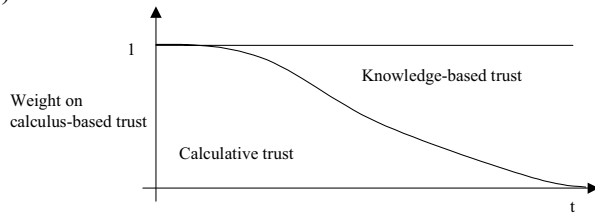


Figure 2. Change over time of the character of trust in an interpersonal relationship. Adapted from [12].

The assumption about the shift from calculative trust to knowledge-based trust is also supported by the observations from the HIMS case. As noted, the initial increase in the level of trust of the providers, and thus their decision to get involved in the project, was the result of a series of conversations and correspondence about the legal framework protecting the privacy rights of their clients (institutional trust). The evidence of the existence of such a framework reduced their perception of risk sufficiently for some of them to decide to get involved (calculative trust). Through the facilitated interactions towards the development of the design of the system, they learned about the trustworthiness of BHS, continuing then with the development of HIMS [10].

Consistent to the view of Mayer and his colleagues [17], the model presented in this paper distinguishes three different constructs used commonly as synonyms in the literature: propensity to trust (on the trustor side), trustworthiness (on the trustee side), and trust (understood as a willingness to be vulnerable).

Finally, the last key assumption of our model is that trust is “learned and reinforced, hence a product of ongoing interaction and discussion” [5]. On this way, the main accumulations in the model are different kinds of knowledge produced during the interaction. Each of these accumulations changes over time because of the main activities involved, learning and forgetting. The mathematical representation of the accumulations in the model is shown in the set of equations (1).

$$\frac{d}{dt}(A's\ Knowledge\ about\ B) = (Learning - Forgetting) \quad (1)$$

$$Learning = \text{Frequency of the Interaction} \cdot \text{Learning per interaction} \cdot \text{Effect of previous Knowledge in learning}$$

$$Forgetting = \frac{A's\ Knowledge\ about\ B}{\text{Time to Forget}}$$

The theory of knowledge represented in the equations is consistent with the learning-by-doing approach in organizations [50, 51]. From this perspective, learning in the model is assumed to be a function of experience,

affected by the knowledge previously acquired. In the early stages of the learning process, acquired knowledge facilitates learning with increasing returns. In a second stage, as A gets to know more and more about B, the initial increasing returns from the previous knowledge change into decreasing returns up to a maximum point. In the final stage, as knowledge reaches a saturation point, the effect of the previous knowledge becomes negative, reducing A’s ability to learn gradually to zero. This formulation of learning produces an s-shaped behavior for knowledge. Because of the saturation point selected in the model, the values for knowledge are bounded between 0 and 1, and are interpreted as the percentage of knowledge that A has about B. Our forgetting theory, on the other hand, is consistent with the observations in experimental psychology [52], and it’s formulated as an exponential decay. Although this formulation constitutes the generic view of knowledge, there are some slight variations that will be described when describing each particular stock of knowledge in the model.

6.2.2. Detailed structure of the model. The model that we present here applies to a dyadic situation in which an actor A observes and develops certain level of trust (or distrust) through interactions with actor B. Actor A in our model represents an aggregation of the group of providers in the HIMS case interacting with BHS during the requirements analysis phase of the project (A complete list of the equations in the model can be requested to the authors by email).

6.2.3. Trust. For this form of dyadic analysis it is most useful to consider trust as a matter of belief, a willingness to act [27] or “a more or less consciously chosen policy for handling the freedom of other human agents or agencies” [2]. There are alternative views, in which trust is considered as a behavior [28] or as a social decision or norm [20, 43, 53]. From the belief perspective, however, there is agreement among researchers about using the language of probabilities to describe the dynamic nature of trust [28, 34, 44, 47]. Complete distrust is represented by a probability of 0 (zero), and complete trust by a probability of 1 [34].

On this way, we consider that actor A’s trust in actor B is the weighted average from 2 probabilities, one that is primarily calculative in nature (calculative trust), and a second one that is developed through the interaction and the perception of actor B’s trustworthiness (knowledge-based trust) (equation 2).

$$\text{Trust in B} = A's\ Knowledge\ about\ B \cdot A's\ perception\ of\ B's\ trustworthiness + (1 - A's\ Knowledge\ about\ B) \cdot \text{Calculative\ Trust} \quad (2)$$

The calculative component of A's trust in B (equation 3) is conceptualized as a function of the risk of being involved, A's interest to get involved with B (desirability), and A's attitude toward risk working as a threshold point [2, 17, 25, 34, 46]. A's attitude to risk constitutes the normal desirability-to-risk ratio for actor A in a given situation calling for trust. When this value is less than 1, it means that actor A can manage situations where risk is greater than desirability (risk seeking). When the attitude towards risk is bigger than one, it means that actor A prefers situations where desirability is bigger than risk (risk avoiding).

$$\text{Calculative Trust} = f\left(\frac{\frac{\text{Desirability}}{\text{Risk}}}{\text{A's attitude to risk}}\right) \quad (3)$$

The ratio in equation 3 is transformed into a probability value by the nonlinear function shown in figure 3. When the ratio is equal to 1, the actual desirability-to-risk calculation is equal to actor A's attitude towards risk, and we have assigned for this particular case a probability of 0.5. When the ratio is bigger than 1, the desirability to risk ratio is bigger than the attitude to risk, increasing the probability to act. A value smaller than one represents the situation in which the desirability to risk ratio is below our normal expectation, reducing the probability to act only on terms of the calculation.

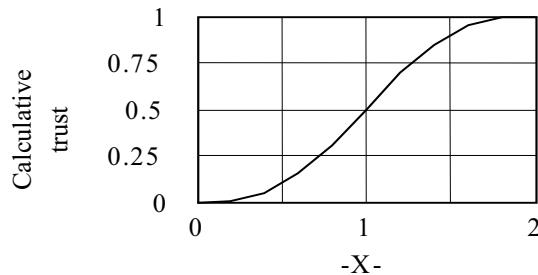


Figure 3. Nonlinear function of the probability associated with calculative trust

The three variables involved in the calculative component of trust are context dependent because each opportunity to collaborate will present different levels of risk and desirability, and actor A's attitude to risk can vary from one situation to another. Although the three of them are also dynamic in nature, a simplifying assumption of the model used here is that these three variables can be treated as constants.

6.2.4. Perception of Trustworthiness. The calculative component represents only one of the two main components of trust in the model. The second component, the perception of trustworthiness, is also conceptualized

as a weighted average between an *a priori* estimate of B's trustworthiness, and a perception developed through the history of the interaction with B (equation 4). A's knowledge about B works again as the weight in the equation, making the history-based component more important as A learns more about B.

Evidence for this two components in the perception of trustworthiness abound in the literature. The *a priori* component can be the result of demographic and social similarities such as gender, race, or position in the organizational structure [31], or the long-term experiences (prejudices or schemas) of the trustor with a particular kind of trustees [28, 42, 43]. The history-based component, on the other hand, is based on data obtained through the interactions between the two actors [42, 43]. Klimoski [43] describes a shift from the *a priori* estimate to the history-based perception of trustworthiness.

$$\begin{aligned} \text{A's perception of B's trustworthiness} = & \\ & \text{A's Knowledge about B} \cdot \\ & \text{History_based perception of trustworthiness} + \\ & (1 - \text{A's Knowledge about B}) \cdot \\ & \text{A priori perception of trustworthiness} \end{aligned} \quad (4)$$

The *a priori* perception of trustworthiness is modeled as a constant that can take values between zero and one. The history-based perception of trustworthiness, on the other hand, is associated in the model with the two reinforcing processes, and the exogenous inputs shown in figure 4. The processes and inputs shown in the figure represent A's perceptual bias, and the rest of the conceptual elements related with the path dependence character of A's trust in B.

As it is shown in the picture, the history-based perception of trustworthiness is equal to the proportion of good experiences in the interaction with actor B. Both good and bad experiences are registered and forgotten in A's memory according to the basic rates of learning and forgetting from the generic knowledge model described at the beginning of this section. In turn, the accumulation of good and bad experiences are the result of a classification process resulting from A's assessment resulting from B's observed behaviors, which are modeled as a series of signs sent by actor B [25] modified by noise, modeled as a series of random numbers. A's assessment resulting from B's behavior, is also modified by A's perceptual bias. That is to say, when the combination of the history-based and the *a priori* perception of trustworthiness show that B is a trustworthy party, A will tend to inflate the assessment of future observations of B's behavior and vice versa.

Perceptual biases such as the ones represented in the model are well documented in the trust literature [25, 28, 43]. A series of heuristics used by the trustor in the perceptual process (availability, anchoring and adjusting,

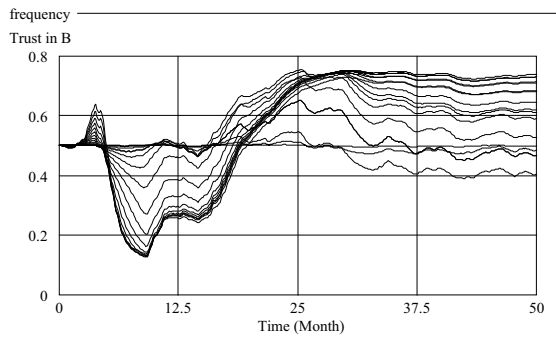


Figure 7. Model behavior with different frequencies of the interaction for trust

The highest interaction frequency patterns are the ones that show large fluctuations in the early time periods, then move upwards to high trust levels that remain high. The low frequency patterns show much smaller initial fluctuations and tend to lower levels of trust at the end point. Paths with high frequency interactions, interpreted as faster learning, may be more volatile at first, since information that can change perception is flowing in at a higher rate. But other factors being equal, the more extensive knowledge base generated thereby leads ultimately to higher levels of trust. On the other hand, higher frequencies of interaction are also associated with more stable levels of trust, suggesting that actor A will tend to be more certain about these subjective probabilities as the frequency of the interaction increases.

A third experiment randomly varied the propensity to trust: party A's propensity to trust party B. The final values over 500 runs were tallied for A's trust in B. The frequencies for these outcomes are shown in the histogram in Figure 8.

This pattern of results can be interpreted as evidence of a nonlinear path dependence process. A model of a linear path dependent process would be expected to produce a random (rectangular) distribution of this sort of random trial. In a nonlinear path dependent process, small initial random variations leading to either greater or lesser trust would bias later interactions in the same directions. Over time, this would lead to the observed bimodal distribution of outcomes. That is, mid-range levels of trust are less likely to be found over time than either high or low levels.

8. Discussion

The dynamic behavior of this model, at least in the limited number of tests performed this far, shows a promising relationship with the behavioral data on which it is based as well as with the related research on trust and knowledge. The wide range of definitions, research findings, and theory about these two important concepts

suggests that their interaction is highly complex. However the simplifications employed in this model produce plausible behavior. This structure treating trust and distrust as simply variations on a single dimension can yield, with reasonable assumptions about asymmetry, path dependent patterns of trust development and asymmetrical outcomes. A learning component that treats good and bad experiences as separate stocks, linked to different remembering and forgetting functions, yields patterns of trust development over time that vary in plausible ways.

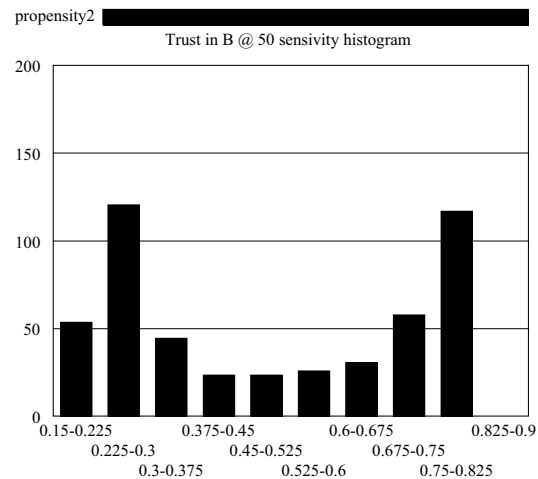


Figure 8. Frequency distribution of the final values of trust for 500 experiments varying the propensity to trust

Putting learning or experience along with an *a priori* predisposition to trust as independent variables, both influencing perceptions of trustworthiness, is an important element in the model structure. Existing research strongly supports the importance of both learning and predispositions as important factors in overall trust formation. However, there is little available in direct research on how experience affects trust development independent of these predispositions. But the model allows some exploration of these relationships, as shown initially above, and suggests possible hypotheses for further simulation and field research. One such hypothesis, based on the patterns over time of trust development (Figure 7), is that learning can overwhelm the effects of predispositions when new information comes at a high rate, leading to the large amplitude fluctuations in the high frequency interaction paths. Thus a way to overcome strong negative predispositions to trust, for example, would suggest a strategy of high frequency interactions and lots of opportunity for learning to build trust.

The model also contains two sources of bias: *a priori* predispositions to trust and different importance of good versus bad experiences in trust development. These are of

considerable theoretical interest. The dynamic behavior of the model with the *a priori* predisposition held constant supports the idea that these predispositions may be quite stable and still provide for wide variations in actual trust development. It is of considerable theoretical and practical importance to understand how important these predispositions are and how stable and even dominant they may be over a range of experience.

These early results of model testing suggest a number of directions for future research. The relative importance of predispositions versus knowledge accumulation can be tested by varying the *a priori* values for predisposition to trust and various patterns of interaction frequency. These results can be prepared to the large body of conflict resolution and negotiation research to see if the model behavior reflects data from additional behavioral studies. The large changes in trust levels in the middle time periods of the experiments reported above suggest that the a function such as calculative trust (equation 2) may be influencing patterns strongly. Experiments can be run to explore the results of alternative assumptions about the nature of this calculation.

Additional behavioral research is underway in the Center for Technology in Government on similar collaborative projects to the one reported here. The case study data from these projects will be used to refine this model and to build additional models of interpersonal and interorganizational interactions. The role of trust and knowledge development in the success of these projects will be explored by combining models of sub processes into larger models of the overall collaboration. The value of the model as a theory building tool will be enhanced by extended data collection and combining with related process models.

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