Trust in computer technology and the implications for design and evaluation

John D. Lee and Katrina A. See

Department of Mechanical and Industrial Engineering
University of Iowa
Iowa City, IA 52242

Abstract

Computer technology is pervasive and often problematic, and the sociological construct of trust has emerged as an important intervening variable to describe reliance on technology. Trust is an important mechanism for coping with the cognitive complexity that accompanies increasingly sophisticated technology. Because of this, understanding trust can help explain reliance on technology and human performance in complex systems. This review characterizes trust by summarizing organizational, sociological, interpersonal, and neurological perspectives. These perspectives provide a clear definition of trust, account of how individual differences influence trust, and describe how characteristics of technology affect trust. A conceptual model integrates these findings and highlights the importance of closed-loop dynamics, the role of context, and the influence of display characteristics. This model has important implications for how systems should be designed to calibrate trust and encourage appropriate reliance. Design and evaluation of technologically intensive systems should consider the calibration of trust if they are to be effective. The growing cognitive complexity that accompanies computer-mediated collaboration and multi-agent automation makes understanding trust increasingly important.

Introduction

Sophisticated information technology is becoming ubiquitous, appearing in work environments as diverse as aviation, maritime operations, process control, motor vehicle operation, and information retrieval. Automation is information technology that actively transforms data, makes decisions, or controls processes. Automation exhibits tremendous potential to extend human performance and improve safety, however, recent disasters indicate that it is not uniformly beneficial. In one case pilots, trusting the ability of the autopilot, failed to intervene and take manual control even as the autopilot crashed an Airbus A320 (Sparaco, 1995). In another instance, an automated navigation system malfunctioned and the crew failed to intervene, allowing the Royal Majesty cruise ship to drift off course for 24 hours before it ran aground (Lee & Sanquist, 2000). On the other hand, people are not always willing to trust in automation. Operators rejected automated controllers in paper mills, undermining the potential benefits of the automation (Zuboff, 1988). As information technology becomes more prevalent, poor partnerships between people and automation will become increasingly costly and catastrophic.

Misuse and disuse describe poor partnerships between automation and people (Parasuraman & Riley, 1997). Misuse refers to the failures that occur when people inadvertently violate critical assumptions and rely on automation inappropriately, whereas disuse signifies failures that occur when people reject the capabilities of automation. Misuse and disuse are two examples of inappropriate reliance on automation that can compromise safety and profitability in many situations. Understanding how to mitigate disuse and misuse of automation is a critically important problem with broad ramifications. Understanding the role of trust in human-automation relationships may help address misuse and disuse.

Several lines of recent research suggest that misuse and disuse of technology depend on certain emotions and attitudes of users, such as trust. In particular, many studies show that humans respond socially to technology and treat computers as they would other human collaborators. For example, the similarity attraction hypothesis in social psychology predicts people with similar personality characteristics will be attracted to each other. This finding also predicts user acceptance of software (Nass, Moon, Fogg, Reeves, & Dryer, 1995; Reeves & Nass, 1996). Software that displays personality characteristics similar to those of the user tends to be more readily accepted. Similarly, the concept of affective computing suggests that computers that can sense and respond to user's emotional states may greatly improve human-computer interaction (Norman, Ortony, & Russell, in press; Picard, 1997). In considering emotion in the design of technology, designers must recognize that techniques that increase acceptance or trust do not necessarily improve performance. The critical challenge is to calibrate trust to encourage appropriate reliance.

Trust seems particularly important for understanding human interaction with automation. More generally, the construct of trust and credibility may also apply to computer-mediated collaboration, where a person may

work with automation, multiple automated agents, or other people through automated intermediaries. Trust and credibility become important when computers play an active and visible role in mediating how people interact with data or the environment (Tseng & Fogg, 1999). Considerable research has shown that trust is an important attitude that mediates how people rely on each other (Deutsch, 1958; Deutsch, 1969; Rempel, Holmes, & Zanna, 1985; Ross & LaCroix, 1996; Rotter, 1967). Sheridan has argued that just as trust mediates the relationships between people; it may also mediate the relationship between people and automation (Sheridan & Hennessy, 1984). A series of experiments have demonstrated that trust is an attitude toward automation that affects reliance, and that it can be measured consistently (Lee & Moray, 1992; Lee & Moray, 1994; Lewandowsky, Mundy, & Tan, 2000; Moray, Inagaki, & Itoh, 2000; Muir & Moray, 1996).

Trust and Complexity: Organizational, Sociological, and Interpersonal Perspectives

Researchers from a broad range of disciplines have examined the role of trust in mediating relationships between organizations, between individuals and organizations, and between individuals. Specifically, trust plays a critical role in interpersonal relationships, where the focus is often on romantic relationships (Rempel et al., 1985). Exchange relationships represent another important research area, where the focus is trust between management and employees and supervisors and subordinates (Tan & Tan, 2000). Trust has an important role in organizational productivity and strengthening organizational commitment (Nyhan, 2000). Trust between firms and customers has also become an important consideration in the context of relationship management (Morgan & Hunt, 1994) and internet commerce (Muller, 1996). Researchers have even considered the issue of trust in the context of the relationship between organizations such as multinational firms (Ring & Vandeven, 1992), where cross-disciplinary and cross-cultural collaboration is critical (Doney, Cannon, & Mullen, 1998). Interest in trust has grown dramatically in the last five years as many have come to recognize the importance of trust in promoting efficient transactions and cooperation. Trust has emerged as a central focus of organizational theory (Kramer, 1999), has been the focus of a recent special issue of the Academy of Management Review (Jones & George, 1998), a workshop at Computer Human Interaction 2000 (Corritore, Kracher, & Wiedenbeck, 2001), and a book (Kramer & Tyler, 1996).

The general theme of the increasing cognitive complexity of work explains the recent interest in trust. Trust tends to be less important in well-structured, stable environments such as procedure-based hierarchical organizations, where an emphasis on order and stability minimize transactional uncertainty (Moorman, Deshpande, & Zaltman, 1993). Many organizations, however, have recently adopted agile structures, self-directed work groups, and complex automation, all of which make the workplace increasingly complex, unstable, and uncertain. Because these changes enable rapid adaptation to change and accommodate unanticipated variability, there is a trend away from well-structured, procedure-based environments. These changes have the potential to make organizations and individuals more productive, but they also increase cognitive complexity and leave more degrees of freedom to the person to resolve. Trust plays a critical role in people's ability to accommodate the cognitive complexity and uncertainty that accompanies these changes.

Trust helps accommodate complexity in several ways. It supplants supervision when direct observation becomes impractical, and facilitates choice under uncertainty by acting as a social decision heuristic (Kramer, 1999). It also reduces uncertainty in estimating the response of others to guide appropriate reliance and generate a collaborative advantage (Baba, 1999; Ostrom, 1998). Moreover, trust facilitates decentralization and adaptive behavior. The increased complexity and uncertainty behind the increased interest in trust in other fields parallels the increased complexity and sophistication of automation. Trust in automation guides effective reliance when the complexity of the automation makes a complete understanding impractical and when the situation demands adaptive behavior that cannot be guided by procedures. For this reason, the recent research on trust provides a rich theoretical base for understanding reliance on complex automation and, more generally, how it affects computer-mediated collaboration that involves both human and computer agents.

The Dynamics of Trust

Figure 1 summarizes the factors affecting trust and the role of trust in mediating reliance. The grey line that links the level of trust to the performance of the automation highlights calibration of trust as a central consideration for guiding appropriate reliance. There are four critical elements in this framework: the relationship between trust and reliance, the closed-loop dynamics of trust and reliance, the importance of context in mediating trust and its effect on reliance, and the role of information display on developing appropriate trust. The research addressing trust between people provides a basis for elaborating this framework to understand the relationship between trust and reliance.

Trust and reliance: Belief, attitude, intention and behavior

Understanding the nature of trust depends on defining the relationship between dispositions, beliefs, attitudes, intentions, and behaviors. These distinctions are of great

theoretical importance because multiple factors mediate the process of translating an attitude into a behavior. Considering trust as a behavior can generate confusion by attributing effects to trust that are due to other factors affecting intention or reliance (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). An approach that keeps attitudes, intention, and behavior conceptually distinct provides a strong theoretical framework for understanding the role of trust in automation.

According to this framework, beliefs represent the information base that determines attitudes. An attitude is an affective evaluation of beliefs that serves as a general predisposition to a set of intentions. Intentions then translate into behavior according to the environmental and cognitive constraints a person faces. According to this logic, definitions of trust should focus on the attitude rather than the beliefs that underlie trust or the intentions or behaviors that might result from different levels of trust. Considering trust as an intention or behavior has the potential to confuse the effect of trust on behavior with other factors such as workload, situation awareness, and self-confidence of the operator (Lee & Moray, 1994; Riley, 1989). No direct relationship between trust and intention or behavior exists because other psychological and environmental constraints intervene. Trust is an attitude that influences intention and behavior. Figure 1 shows that trust stands between beliefs about the characteristics of the automation and the intention to rely on the automation.

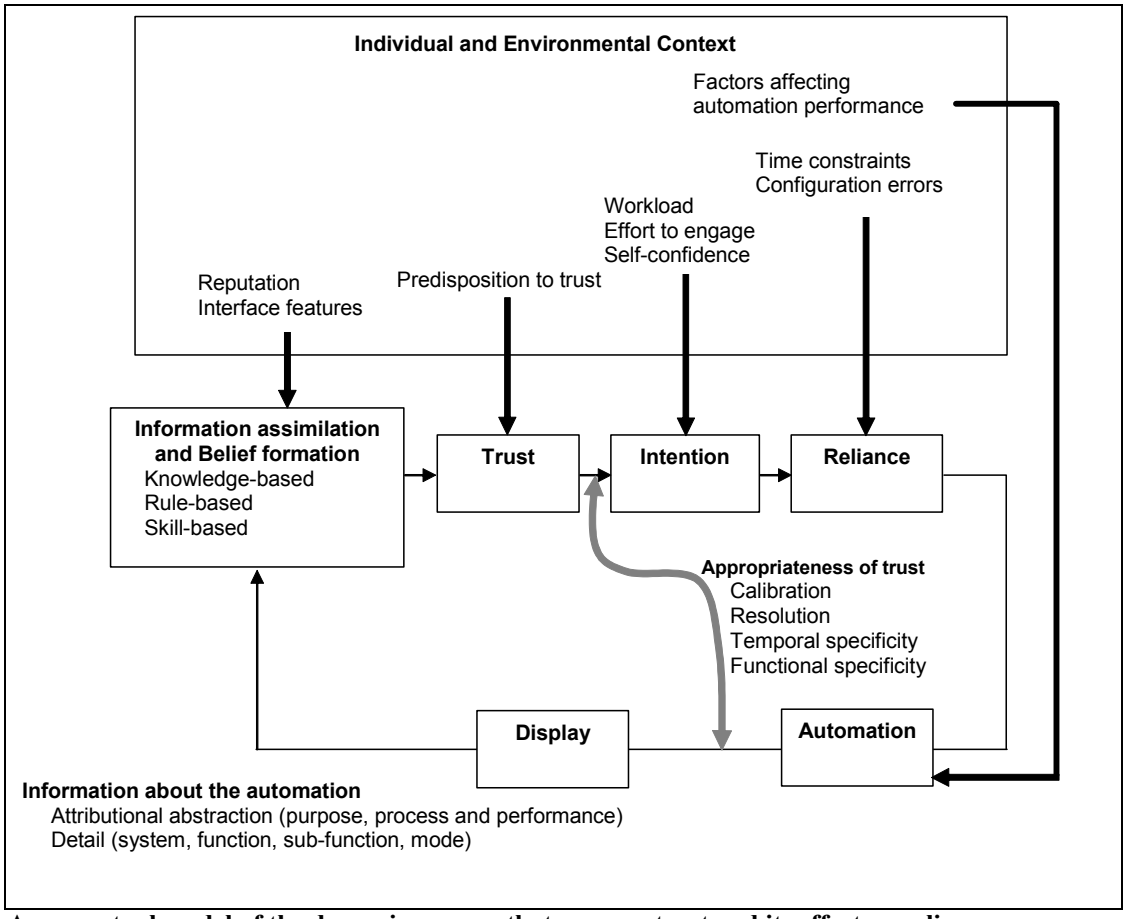

Figure 1. A conceptual model of the dynamic process that governs trust and its effect on reliance.

The cognitive processes associated with trust

The information that forms the basis of trust can be assimilated in several qualitatively different ways. Some argue that trust depends on a calculative process; others argue that trust depends on the application of rules. Most importantly, trust also seems to depend on an affective response to the violation or confirmation of implicit expectancies. The affective and calculative aspects of trust depend on the evolution of the relationship between the trustor and trustee, the information available to the trustor, and the way the information is displayed.

A dominant approach to trust in the organizational sciences considers trust from a rational choice perspective (Hardin, 1992). This view considers trust as an evaluation made under uncertainty in which decision makers use their knowledge of the motivations and interests of the other party to maximize gains and minimize losses. Individuals

are assumed to make choices based on a rationally derived assessment of costs and benefits (Lewicki & Bunker, 1996). Williamson (1993) argues that trust is primarily calculative in business and commercial relations and that trust represents one aspect of rational risk analysis. Trust accumulates and dissipates based on the cumulative interactions with the other agent. These interactions lead to an accumulation of knowledge that establishes trust through an expected value calculation, where the probability of various outcomes is estimated with increasing experience (Holmes, 1991).

Trust can also develop according to rules that link levels of trust to characteristics of the agent. These can develop through direct observation of the trusted agent, intermediaries that convey their observations, and presumptions based on standards, category membership, and procedures (Kramer, 1999). Trust may depend on the application of rules rather than on conscious calculations. Explicit and implicit rules frequently guide individual and collective collaborative behavior (Mishra, 1996). Sitkin and Roth (1993) illustrate the importance of rules in their distinction between trust as an institutional arrangement and interpersonal trust. Institutional trust reflects the use of contracts, legal procedures, and formal rules, whereas interpersonal trust depends on shared values. The application of rules in institution-based trust reflects guarantees and safety nets based on the organizational constraints of regulations, guarantees, and legal recourse that constrain behavior and make it more possible to trust (McKnight, Cummings, & Chervany, 1998). Institution-based trust increases people's expectation of satisfactory performance during times of normal operation by pairing situations with rule-based expectations.

Intermediaries can also convey information to support judgments of trust (Baba, 1999). Similarly, trust can be based on presumptions of the trustworthiness of a category or role of the agent rather than on the actual performance of the agent (Kramer, 1999). If trust depends on rules that characterize performance during normal situations, then abnormal situations can lead trust to collapse because the assurances associated with normal or customary operation are no longer valid. Because of this, role and category-based trust can be fragile, particularly when abnormal situations disrupt otherwise stable roles.

Calculative and rule-based processes do not account for the affective characteristics of trust, and fail to consider the social and affective aspects of trust (Kramer, 1999). Emotional responses are critical because people not only think about trust, they also feel it (Fine & Holyfield, 1996). Emotions fluctuate over time according to the performance of the other agent, and they can signal instances where expectations do not conform to the ongoing experience. As trust is betrayed, emotions provide signals concerning the changing nature of the situation (Jones & George, 1998).

Berscheid (1994) uses the concept of automatic processing to describe how events that are relevant to affective trait constructs, such as trust, are likely to be perceived even under attentional overload situations. Because of this, people process observations of new behavior according to these constructs without always being aware of doing so. Automatic processing plays a substantial role in attributional activities, with many aspects of causal reasoning occurring outside conscious awareness. In this way, emotions bridge the gaps in rationality and enable people to focus their limited attentional capacity (Johnson-Laird & Oately, 1992). Because the cognitive complexity of relationships can exceed a person's capacity to form a complete mental model, people cannot perfectly predict behavior, and emotions serve to redistribute cognitive resources, manage priorities, and make decisions with imperfect information (Johnson-Laird & Oately, 1992). This is particularly critical when rules fail to apply and when cognitive resources are not available to support a calculated rational choice. The affective nature of trust seems to parallel some of the features of skill-based behavior, where an internalized dynamic world model guides behavior without conscious intervention (Rasmussen, 1983).

Recent neurological evidence parallels these findings, indicating that emotions play an important role in decision-making. This research is important because it suggests a neurologically-based description for how trust might influence reliance. Damasio (1990) showed that although people with brain lesions in the ventromedial sector of the prefrontal cortices retain reasoning and other cognitive abilities, their emotions and decision-making ability are critically impaired. In a simple gambling decision-making task, those with prefrontal lesions performed much worse than a control group of normal people. Patients responded to immediate prospects and failed to accommodate long-term consequences (Bechara, Damasio, Damasio, & Anderson, 1994). In a subsequent study, normal subjects showed a substantial response to a large loss, as measured by skin conductance response (SCR), a physiological measure of emotion, whereas patients did not (Bechara, Damasio, Tranel, & Damasio, 1997). Interestingly, normal subjects also demonstrated an anticipatory SCR and began to avoid risky choices before they explicitly recognized the alternative as being risky. These results strongly support the argument that emotions play an important role in decision-making, and that emotional reactions may mediate trust without conscious awareness.

Emotion influences not only individual decision making but also the decision making of groups, suggesting that affect-based trust may play an important role in governing reliance on automation. Emotion plays an important role in decision making by supporting implicit communication between several people (Pally, 1998). The tone, rhythm and quality of speech convey information about the

emotional states of individuals, and so regulate the physiological emotional responses of everyone involved. People spontaneously match non-verbal cues to generate emotional attunement. Emotional, non-verbal exchanges are a critical complement to the analytic information in a verbal exchange (Pally, 1998). These neuropsychological results seem consistent with recent findings regarding interpersonal trust in which anonymous computerized messages were found to be not as effective as face-to-face communication because individuals judge trustworthiness from facial expressions and from hearing the way others talk (Rocco, 1998). These results suggest that trust calibration could be aided by incorporating a rich array of informal cues into the computer interface. These cues might begin to replicate the emotional attunement of face-to-face interactions between people.

Results from many studies show that develops and influences behavior in more than one way. Trust between individuals and in automation likely depends on a complex interaction of knowledge-based calculations, rule-based categorizations, and most importantly, the implicit skill-based interpretation of information.

The dynamic process of trust and reliance

Figure 1 shows that trust and its effect on reliance are part of a closed-loop process, where the dynamic interaction with the automation governs trust. If the system is not trusted, it is unlikely to be used; if it is not used, the person will have limited information regarding its capabilities and it is unlikely that trust will grow. Because trust is largely based on the observation of the automation, automation must be relied upon for trust to grow (Muir & Moray, 1996). Relying on automation provides operators with an opportunity to observe the automation and thus to develop increasingly greater levels of trust.

The dynamic interplay between changes in trust, the effect of these changes on reliance, and the resulting feedback can generate substantial non-linear effects. The non-linear cascade of effects noted in the dynamics of interpersonal trust (Ostrom, 1997) and the high degree of volatility in the level of trust in some relationships suggests a similar phenomena occurs between people (McKnight et al., 1998). This non-linear behavior may also account for the large individual differences noted in human-automation trust (Lee & Moray, 1994; Moray et al., 2000). A small difference in the predisposition to trust may have a substantial effect when it influences an initial decision to engage the automation. A small difference in the initial level of trust might, for example, lead one person to engage the automation and another to adopt manual control. Reliance on the automation may then lead to a substantial increase in trust, whereas the trust of the person who adopted manual control might decline. Characterizing the dynamics of the feedback loop shown in Figure 1 is essential to understanding why trust sometimes appears volatile and other times stable. This closed-loop framework also highlights the importance of temporal specificity in characterizing the appropriateness of trust. The higher the temporal specificity, the more likely that trust will correspond to the current capability of the automaton. Poor temporal specificity will act as a time delay, undermining system stability and increasing the volatility of trust. The closed loop feedback may explain how operator, environment, and automation characteristics combine over time to affect trust and reliance.

Context and trust

Figure 1 shows that trust is an intervening variable that indirectly influences intention and reliance. Beliefs combine with individual differences, such as the predisposition to trust, to determine the level of trust in the automation. Predisposition to trust is most important when a situation is ambiguous and generalized expectancies dominate, and becomes less important as the relationship progresses (McKnight et al., 1998). The level of trust combines with other attitudes and expectations such as subjective workload and self-confidence to determine the intention to rely on the automation. Self-confidence is particularly critical factor in decision making in general (Bandura, 1982; Gist & Mitchell, 1992) and in mediating the effect of trust on reliance in particular (Lee & Moray, 1994). A variety of system and human performance constraints affect how the intention to rely on automation translates into actual reliance (Kirlik, 1993). For example, the operator may intend to use the automation but not have sufficient time to engage it. Understanding the role of trust in the decision to rely on automation requires a consideration of the operating context that goes beyond trust alone.

The conceptual model in Figure 1 helps integrate the research from psychology, sociology, and management science. Most importantly, it shows that trust depends on the dynamic interaction between operator, environment, and automation characteristics.

Conclusions

A substantial research base from several disciplines suggests that trust is an important mechanism to cope with the increasing cognitive complexity associated with new technology. In particular, research shows that trust mediates reliance on automation. This review describes a conceptual model of trust that can guide research and design. Specific conclusions include:

- Trust influences reliance as an attitude in the context of beliefs, attitudes, intentions, and behavior. Reliance is not a good measure of trust.
- Designers should focus on calibrating trust not necessarily enhancing trust. Maximizing trust is often a poor design goal.

- Trust depends on information assimilated through calculative-, rule-, and skill-based processes. Calibrating trust requires interface design that considers qualitatively different cognitive processes that influence trust.
- Dynamic relationship between person and automation helps explain non-linear characteristics of trust and reliance. Trust and reliance may evolve over time in highly variable and counterintuitive ways.
- Interface design should capitalize on people's ability to process affective stimuli. Interface design should incorporate subtle cues that guide interpersonal responses, such as auditory cues associated with verbal inflections, sighs, and pauses to indicate uncertainty.
- Systems that mimic human characteristics, may inadvertently lead to inappropriate levels of trust as the human characteristics lead to false expectations. Human-like features should not be arbitrarily incorporated into a design, but should be carefully designed to calibrate trust.

These general points provide important considerations for how systems might be designed and evaluated to enhance trust calibration.

Acknowledgements

This work was supported by a grant from the NSF, IIS 01-17494.

References

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Upper Saddle River, New Jersey: Prentice Hall.

Baba, M. L. (1999). Dangerous liaisons: Trust, distrust, and information technology in American work organizations. *Human Organization, 58*(3), 331-346.

Bandura. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*, 122-147.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*(1-3), 7-15.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275*(5304), 1293-1295.

Berscheid, E. (1994). Interpersonal relationships. *Annual Review of Psychology, 45*, 79-129.

Corritore, C. L., Kracher, B., & Wiedenbeck, S. (2001). *Trust in the online environment*. Seattle, WA: CHI workshop.

Damasio, A. R., Tranel, D., & Damasio, H. (1990). Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social-stimuli. *Behavioural Brain Research, 41*(2), 81-94.

Deutsch, M. (1958). Trust and suspicion. *Journal of Conflict Resolution, 2*(4), 265-279.

Deutsch, M. (1969). Trust and suspicion. *Conflict Resolution, III*(4), 265-279.

Doney, P. M., Cannon, J. P., & Mullen, M. R. (1998). Understanding the influence of national culture on the development of trust. *Academy of Management Review, 23*(3), 601-620.

Fine, G. A., & Holyfield, L. (1996). Secrecy, trust, and dangerous leisure: Generating group cohesion in voluntary organizations. *Social Psychology Quarterly., 59*(1), 22-38.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention, and Behavior*. Reading, MA: Addison-Wesley.

Gist, M. E., & Mitchell, T. R. (1992). Self-efficacy - A theoretical-analysis of its determinants and malleability. *Academy of Management Review, 17*(2), 183-211.

Hardin, R. (1992). The street-level epistemology of trust. *Politics and Society, 21*, 505-529.

Holmes, J. G. (1991). Trust and the appraisal process in close relationships. In W. H. Jones & D. Perlman (Eds.), *Advances in Personal Relationships* (Vol. 2, pp. 57-104). London: Jessica Kingsley.

Johnson-Laird, P. N., & Oately, K. (1992). Basic emotions, rationality, and folk theory. *Cognition and Emotion, 6*, 201-223.

Jones, G. R., & George, J. M. (1998). The experience and evolution of trust: Implications for cooperation and teamwork. *Academy of Management Review, 23*(3), 531-546.

Kirlik, A. (1993). Modeling strategic behavior in human-automation interaction: Why an "aid" can (and should go unused. *Human Factors, 35*(2), 221-242.

Kramer, R. M. (1999). Trust and distrust in organizations: Emerging perspectives, enduring questions. *Annual Review of Psychology, 50*, 569-598.

Kramer, R. M., & Tyler, T. R. (1996). *Trust in organizations: Frontiers of theory and research*. Thousand Oaks, CA: Sage Publications.

Lee, J., & Moray, N. (1992). Trust, control strategies and allocation of function in human-machine systems. *Ergonomics, 35*(10), 1243-1270.

Lee, J. D., & Moray, N. (1994). Trust, self-confidence, and operators' adaptation to automation. *International Journal of Human-Computer Studies, 40*, 153-184.

Lee, J. D., & Sanquist, T. F. (2000). Augmenting the operator function model with cognitive operations: Assessing the cognitive demands of technological innovation in ship navigation. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 30*(3), 273-285.

Lewandowsky, S., Mundy, M., & Tan, G. (2000). The dynamics of trust: Comparing humans to automation. *Journal of Experimental Psychology-Applied, 6*(2), 104-123.

Lewicki, R. J., & Bunker, B. B. (1996). Developing and maintaining trust in work relationships. In R. M. Kramer & T. R. Tyler (Eds.), *Trust in organizations: Frontiers of theory and research* (pp. 114-139). Thousand Oaks, CA: Sage Publishers.

McKnight, D. H., Cummings, L. L., & Chervany, N. L. (1998). Initial trust formation in new organizational relationships. *Academy of Management Review, 23*(3), 473-490.

Mishra, A. K. (1996). Organizational response to crisis. In R. M. Kramer & T. R. Tyler (Eds.), *Organizational trust: Frontiers of research and theory* (pp. 261-287). Thousand Oaks, CA: Sage Publishers.

Moorman, C., Deshpande, R., & Zaltman, G. (1993). Factors affecting trust in market-research relationships. *Journal of Marketing, 57*(1), 81-101.

Moray, N., Inagaki, T., & Itoh, M. (2000). Adaptive automation, trust, and self-confidence in fault management of time-critical tasks. *Journal of Experimental Psychology-Applied, 6*(1), 44-58.

Morgan, R. M., & Hunt, S. D. (1994). The commitment-trust theory of relationship marketing. *Journal of Marketing, 58*(3), 20-38.

Muir, B. M., & Moray, N. (1996). Trust in automation 2: Experimental studies of trust and human intervention in a process control simulation. *Ergonomics, 39*(3), 429-460.

Muller, G. (1996). Secure communication - Trust in technology or trust with technology? *Interdisciplinary Science Reviews, 21*(4), 336-347.

Nass, C., Moon, Y., Fogg, B. J., Reeves, B., & Dryer, D. C. (1995). Can computer personalities be human personalities? *International Journal of Human-Computer Studies, 43*, 223-239.

Norman, D. A., Ortony, A., & Russell, D. M. (in press). Affect and machine design: Lessons for the development of autonomous machines. *IBM Systems Journal*.

Nyhan, R. C. (2000). Changing the paradigm - Trust and its role in public sector organizations. *American Review of Public Administration, 30*(1), 87-109.

Ostrom. (1997).

Ostrom, E. (1998). A behavioral approach to the rational choice theory of collective action. *American Political Science Review, 92*(1), 1-22.

Pally, R. (1998). Emotional processing: The mind-body connection. *International Journal of Psycho-Analysis, 79*, 349-362.

Parasuraman, R., & Riley, V. (1997). Humans and Automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 230-253.

Picard, R. W. (1997). *Affective computing*. Cambridge, Mass.: MIT Press.

Rasmussen, J. (1983). Skills, rules, and knowledge: Signals, signs, and symbols, and other distinctions in human performance models. *SMC-13*(3), 257-266.

Reeves, B., & Nass, C. (1996). *The Media Equation: How people treat computers, television, and new media like real people and places*. New York: Cambridge University Press.

Rempel, J. K., Holmes, J. G., & Zanna, M. P. (1985). Trust in close relationships. *Journal of Personality and Social Psychology, 49*(1), 95-112.

Riley, V. (1989). *A general model of mixed-initiative human-machine systems.* Paper presented at the Proceedings of the Human Factors Society 33rd Annual Meeting.

Ring, P. S., & Vandeven, A. H. (1992). Structuring cooperative relationships between organizations. *Strategic Management Journal, 13*(7), 483-498.

Rocco, E. (1998). Trust breaks down in electronic contexts bu can be repaired by some initial face-to-face contact. *Proceedings on Human Factors in Computing Systems*, 496-502.

Ross, W., & LaCroix, J. (1996). Multiple meanings of trust in negotiation theory and research: A literature review and integrative model. *International Journal of Conflict Management, 7*(4), 314-360.

Rotter, J. B. (1967). A new scale for the measurement of interpersonal trust. *Journal of Personality, 35*(4), 651-665.

Sheridan, T. B., & Hennessy, R. T. (1984). *Research and modeling of supervisory control behavior*. Washington, D.C.: National Academy Press.

Sitkin, S. B., & Roth, N. L. (1993). Explaining the limited effectiveness of legalistic remedies for trust distrust. *Organization Science, 4*(3), 367-392.

Sparaco, P. (1995). Airbus seeks to keep pilot, new technology in harmony. *Aviation Week and Space Technology, January 30,* 62-63.

Tan, H. H., & Tan, C. S. (2000). Toward the differentiation of trust in supervisor and trust in organization. *Genetic, Social, and General Psychological Monographs, 126*(2), 241-260.

Tseng, S., & Fogg, B. J. (1999). Credibility and computing technology. *Communications of the ACM, 42*(5), 39-44.

Williamson, O. (1993). Calculativeness, trust and economic-organization. *Journal of Law and Economics, 36*(1), 453-486.

Zuboff, S. (1988). *In the age of smart machines: The future of work technology and power*. New York: Basic Books.