A Quantitative Assessment of the Impact of Team Effectiveness on Changes in Individual Trust

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ABSTRACT

In order to be effective, individuals working in distributed teams must learn to trust one another. Trust is a broad term with many operationalizations, yet recent research has supported the notion that there are two important facets of trust for individuals working in teams: affect-based and cognition-based (McAllister, 1995). Although theory assumes the facets evolve at a consistent rate over time (McAllistar, 1995; Wilson, Straus, & McEvily, 2006) there have been no empirical tests of this assumption. We modeled the latent growth of trust over time within individuals who are members of distributed teams. Employing latent change score (LCS) models (an integration of multi-level and structural equation modeling; Ferrer & McArdle, 2011; McArdle, 2009), we demonstrate the ability to identify the dimensionality of trust, quantify its initial level and rate of change over time within individuals, and link it to effectiveness. Working in teams of three, 297 individuals completed three parallel scenarios involving search and rescue in the Antarctic using Aptima's DDD simulator and a scenarios originally developed by NASA. Trust is measured at four points, first using an initial measure and then after the completion of each task. Confirmatory factor analysis established the validity of affect-based and cognition-based trust factors. For each of the trust factors, a full LCS model was tested along with a theoretically plausible alternative model where effectiveness has no influence on change in trust. For both cognition-based and affect-based trust, the full LCS model fit well (Affect-based $\chi 2$ (242)=997, NFI=.967, TLI=.970, CFI=.977; Cognition-based $\chi 2$(242)=1,045, NFI=.965, TLI=.966, CFI=.975) and significantly better than the alternative models (nested model comparisons: Affect-based $\chi 2$ (3)= 403, $p < .001$; Cognition-based $\chi 2$ (3) = 215, $p < .001$). Our work provides several theoretical contributions: addressing the dimensionality of trust, its initial level in individuals, rate of latent growth over time, and impact on effectiveness. Results speak directly to practical issues found in distributed work teams in both the civilian and military sectors.

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INTRODUCTION

Working in teams is a widely observed phenomenon in the workplace, both in the civilian and military sectors. As the complexity of tasks that employees need to perform increases, so does the need for effective teams. Effective teamwork requires collaboration and interaction between team members (Salas, Dickinson, Converse, & Tennenbaum, 1992), which are processes facilitated by trust (Salas, Sims, & Burke, 2005). There are a variety of factors which influence the development of trust between individuals, and one such factor is the setting in which people interact. The rapid development of computer and communication technology has made technology-mediated work and communication commonplace.

Research thus far suggests that technology-mediated teams are inferior compared to face-to-face teams when measuring performance (Anderson, McEwan, Bal, & Carletta, 2007; Thompson & Coovert, 2006). We propose that this inferiority is due to underdeveloped levels of trust between team members resulting from the technology-mediated environment. To address this concern, we examine the development of interpersonal trust in a technology-mediated environment and the relationship between trust and team effectiveness.

Trust

Trust is "the extent to which a person is confident in, and willing to act on the basis of, works, actions, and decisions of another" (McAllister, 1995, pg. 25). It has two distinct components – cognition-based trust and affect-based trust. Cognition-based trust is derived from knowledge about the trustee's competence and reliability. Affect-based trust, on the other hand, captures the emotional ties between the trustor and the trustee. Empirical investigation has confirmed this two-factor structure of trust (e.g., Webber, 2008; Wilson, Straus, & McEvily, 2006; McEvily & Tortoriello, 2011).

Trust is necessary for human relationships; it is central to group participation (Bandow, 2001) and sharing information (Jones & George, 1998). Trust is inseparable from risk and is necessary when there is some level of risk involved. It is a heuristic that allows people to participate in risky behaviors without engaging in a laborious analysis of the risks and benefits of the situation (Riegelsberger, Sasse, & McCarthy, 2003). Trust relates positively to satisfaction, performance, and commitment as well as negatively to stress (Costa, Roe, & Taillieu, 2001; Costa, 2003). It is critical to the communication process and a lack of trust can have negative consequences. For instance, Salas and colleagues determined that in situations when there is a low level of trust, ambiguous information is interpreted more negatively (Salas et al., 2005).

Trust is particularly important for technology-mediated environments for several reasons. First, a computer-mediated interaction can be considered more risky than a face-to-face interaction. When people interact through a technological medium they can be placed in an unfamiliar context or culture, which increases the likelihood of misunderstanding and makes collaboration problematic. These complications make the interaction more complex and thus increase the overall complexity of the task itself. Trust can reduce this complexity by reducing the need for a risk assessment of the interaction itself while engaging in the primary task (Riegelsberger, Sasse, & McCarthy, 2003). Second, the quality of the interaction in a technology-mediated setting is lower than the quality of face-to-face interactions. Technology-supported communication is often inferior to face-to-face communication because it transmits less communication cues (Daft & Lengel, 1986). When people communicate face-to-face they exchange numerous communication cues (e.g. posture, tone of voice, facial expression), which provide information relevant to the interaction. However, when people communicate through technology, some cues are never transmitted during the interaction, making the development of trust harder (Riegelsberger et al., 2003).

Moreover, workers who communicate through technology engage in less informal communication interactions (Cohen & Gibson, 2003) which can result in loneliness, less commitment to the team, and less trust among team members (LeMay, 2000). Lastly, interaction through technology seldom allows the trustor to observe the behaviors of the trustee and either confirm or disconfirm his/her expectation of the trustee's behavior. Since trust is rooted within the trustor's expectations of the trustee's behavior, the inability to follow-up on the trustee's behaviors makes the development of trust problematic (Lewicki, Tomlinson, & Gillepie, 2006).

Present Study

It is evident that there are many challenges to developing trust in a technology-mediated environment. Since trust is important for effective teamwork and team performance, it is desirable to explore how to facilitate its growth in the absence of face-to-face interaction. To begin addressing that question, we examined 1) the development of trust and 2) the relationship between trust and team effectiveness in a technology-mediated environment.

We employed a task-episode approach in studying the trust-team effectiveness link, which allows us to examine the relationship in a longitudinal manner (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008). Methodologically, we examine the trust-effectiveness relationship using a latent change score methodology (LCS; McArdle, 2009; Ferrer & McArdle, 2010). This technique was preferred over others because it allows us to examine possible sources of change in the constructs of interest. Additionally, LCS models include coupling parameters that capture the time-dependent effect of one construct on the change of another, therefore allowing the examination of dynamic processes.

The dynamic relationship of interest is the one postulated to exist between trust and effectiveness, and how the latent growth of each changes and is influenced by the other over time (see Figure 1 for a schematic representation of the model). We expect that trust development will be partially driven by existing levels of trust. Therefore trust during one task-episode will be predicted by trust during the prior task-episode. Similarly, the development of effectiveness will be dependent on the already established effectiveness (practice effects). We anticipate that change in trust (ΔTrust1 and ΔTrust2) will be driven by intra-construct relationships, already established trust (Trust1 and Trust2), as well as inter-construct relationships, namely effectiveness achieved during the task-episode (Effectiveness1 and Effectiveness2). In turn, the changes in effectiveness (ΔEffectiveness1 and ΔEffectiveness2) will be a function of prior effectiveness and trust levels during the task-episode (Trust2 and Trust3).

METHOD

Participants

Two hundred and ninety seven (N=297) participants took part in this study. Each team consisted of four team members, three active members and one coordinating member. The present analyses were restricted to the data obtained from the three active members . Teams with incomplete data due to technical issues were also excluded. Participants were undergraduate students at a large public university in the southeastern US.

Materials

DDD Task. This study utilized a distributed team performance task operated by Aptima's DDD (Distributed Dynamic Decision-making) system, version 4.1, an adaptable simulation platform used widely in team research. The task consisted of three computer-simulated search and rescue missions. Three objectives were required to complete each mission: find and aid the lost party, find and repair a satellite, and find and repair a lost object (e.g., a UAV). The location of the three objectives varied in each mission, and the order of missions was counterbalanced across teams. Team members possessed an equal, finite amount of resources (e.g., medical, mechanical, and technical) that were necessary to accomplish the three objectives in each mission. Two out of the three objectives required at least two team members to pool their resources in order to be solved. Minor tasks, which were performed individually, had to be completed in order to locate the three objectives. Team members communicated with each other via an instant message chat window. There were four participants per team (red, green, purple, and blue). Three participants (red, green, and purple, active team members) were responsible for completing each mission. Since they had a finite amount of resources, one team member (blue, coordinating team member) was responsible for controlling and distributing an external supply of resources as needed. When there were only three participants per team, a research assistant performed the role of the blue member. Teams received points for how well they performed in each scenario.

Team satisfaction. Team satisfaction was assessed using a team satisfaction scale adapted from Lancellotti and Boyd (2008). The scale contained three items that assessed individual desire to be a part of the team. Respondents indicated their level of agreement on a 7-point Likert scale. The scale demonstrated good reliability, ranging from α = .85-.88 across the three measurement periods.

Team trust. Team trust was measured using the trust scale developed by McAllister (1995). The scale assessed two dimensions of trust: affect-based trust (four items) and cognition-based trust (five items). Participants indicated their responses on a 5-point Likert scale. Reliabilities for affect-based and cognition-based trust varied across measurement points within acceptable levels (α=.8-.9 and α = .84-.93, respectively).

Design

This study was designed to meet several requirements of latent change score models. Latent change score models require a minimum of three measurement points to estimate parameters of the latent growth trajectory and linkage between the underlying variables, and an equivalent time lag between measurement events (Ferrer & McArdle, 2010). In accordance with these assumptions, the present study employed a longitudinal design with three measurement points throughout the study session. Each measurement interval was 45 minutes long. Trust was measured at the beginning of the assessment session, prior to the completion of the first mission (Time 1) and again after the completion of the first, second, and third missions (Times 2, 3, and 4, respectively).

Procedure

Participants were recruited via an online university recruiting system and signed up for the study session of their choice. Upon arrival, participants were immediately escorted into separate work stations to limit interaction. After informed consent was obtained, participants completed the initial (Time 1) trust assessment. This was followed by an instructional video on the search and rescue simulation, including how to accomplish each mission and the respective roles of each team member. Next, demographic information was obtained. Participants then completed a training mission that familiarized them with the DDD interface and ensured they were trained to competence. After training was completed, the first mission took place. Participants were given 40 minutes to complete the first mission. After 40 minutes, participants were given the second trust assessment (Time 2) and the first team satisfaction survey. After the team satisfaction survey was completed, participants began the second mission. Upon completion of the second mission (40 minutes), participants were given the third trust assessment (Time 3) and the second team satisfaction survey. Participants then began the third mission (40 minutes). Upon completion of the final mission, participants filled out the fourth trust assessment (Time 4) and third team satisfaction measure. They were then debriefed and thanked for their participation.

RESULTS

The performance score and satisfaction measures received by a team were utilized as indicators for effectiveness. Four items from the trust scale reflecting cognitive trust served as indicators for the estimated cognitive model. The affective trust items replaced those items in the estimated affective trust model. A covariance matrix was computed among measured variables and the latent change score analysis was performed with LISREL 9.1.

Model fit is determined using measures conventionally employed in structural equation modeling. Here we utilize three of the most common measures reflecting how well the model explains the relationships in the data: the Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), and Normed Fit Index (NFI). Values for these indices range between 0 and 1 with values below .90 reflecting a lack of practical fit; .90-.93 mediocre to fair fit; .94-.95 good fit; and above .95 very good fit. The chi-square test of exact fit is reported along with its degrees of freedom. Due to its sensitivity to sample size, the chi-square of exact fit is conventionally not used to assess overall fit but is often used to assess incremental fit when one (nested) model is compared to another. In this case the difference in chi-squares is distributed as a chi-square (with df equal to the difference in df between the two models). Finally, the Expected Cross Validation Index (ECVI) is also used to compare models, with preference going to the model with the smaller ECVI.

Cognitive latent change score model. The model parameters for the cognitive model can be seen in Figure 2. At the bottom of the figure, one can see the four times cognitive trust is measured. The factor loadings are constrained to be equal across the four time points to reflect that the scale itself does not change. All change is attributed to the change in the latent trust construct. The same invariance constraint is imposed upon the team satisfaction items used as indicators of effectiveness. Therefore, the measurement properties of the scale do not change and what is reflected is variance in the construct.

We have three primary questions to ask. The first deals with the fit of the affective and cognitive trust models, the second with the rate of change in trust over time, and the third addresses the influence of effectiveness on change in trust.

Fit of the latent change score model. We assessed the fit of four models to the data. The first two are the full latent change score representations, as seen in Figure 1 (both dashed and solid lines are estimated). The model is estimated once with the affective indicators of trust and a second time with the cognitive indicators of trust. An assessment of the NFI, TLI, and CFI indices indicates that the fit of each of the four models is quite good. ECVI indicates a preference for the complete models for both cognitive and affective trust, with the affective trust model being slightly better than the cognitive trust model. Thus both affective and cognitive trust are important in distributed teams. See Table 1 for a summary.

Rate of change in trust. The second question addresses the rates of change in trust over time. Most theories (McAllister, 1995) assume the rate is constant and linear. Here we explicitly address this question by examining the slopes of the change in trust parameters at Δ Trust1 (change in trust from time1 to time2), ΔTrust2 (change in trust from time2 to time3), and Δ Trust3 (change in trust from time3 to time4). These three slope parameters run from the trust slope latent variable (Trust s) to each of the three change-in-trust latent variables (ΔTrust). See Figure 3 and see again Figure 2. As illustrated by Figure 3, the slopes of the change in trust parameters are different across time periods, suggesting that trust does not change at a constant rate. These findings refute the widely-held notion that trust changes at a uniform rate. On the contrary, our findings indicate that the rate of change decreases as time increases.

Influence of effectiveness on rate of change. The third question focuses on the direct role of effectiveness on influencing change in trust. This is seen by the three structural parameters represented by dashed lines in Figure 1. The complete or full model estimates all parameters, while the alternative does not include those three represented by the dashed lines. A nested model chi-square test was performed to directly compare the complete latent change score model to the alternative. This is performed separately for the affect-based and cognition-based solutions. For affect-based trust, the difference between the complete and alternative models, $\chi 2$ (3) = 403, $p < .001$, indicates that the complete model fits the data significantly better than the alternative. This indicates that effectiveness directly influences changes in affect-based trust. The finding is similar for cognition-based trust, $\chi 2$ (3) = 215, $p < .001$ indicating that the complete model fits the data significantly better than the alternative. The magnitude of the parameters indicate that early and mid effectiveness have greater influence (with parameter estimates of .73 and .74, respectively) than later effectiveness (.20).

Table 1. Overall fit of the models to the data. The Complete LCS models have all structural parameters estimated while the alternative models do not estimate those parameters indicated by the dashed lines (see Figures 1 & 2).

Model	Chi-square	df	NFI	TLI	CFI	ECVI
Affect-based						
Complete LCS	997	242	.967	.970	.977	4.090
Alternative	1400	245	.976	.982	.986	12.16
Cognition-based						
Complete LCS	1045	242	.965	.965	.974	4.928
Alternative	1260	245	.965	.966	.975	11.69

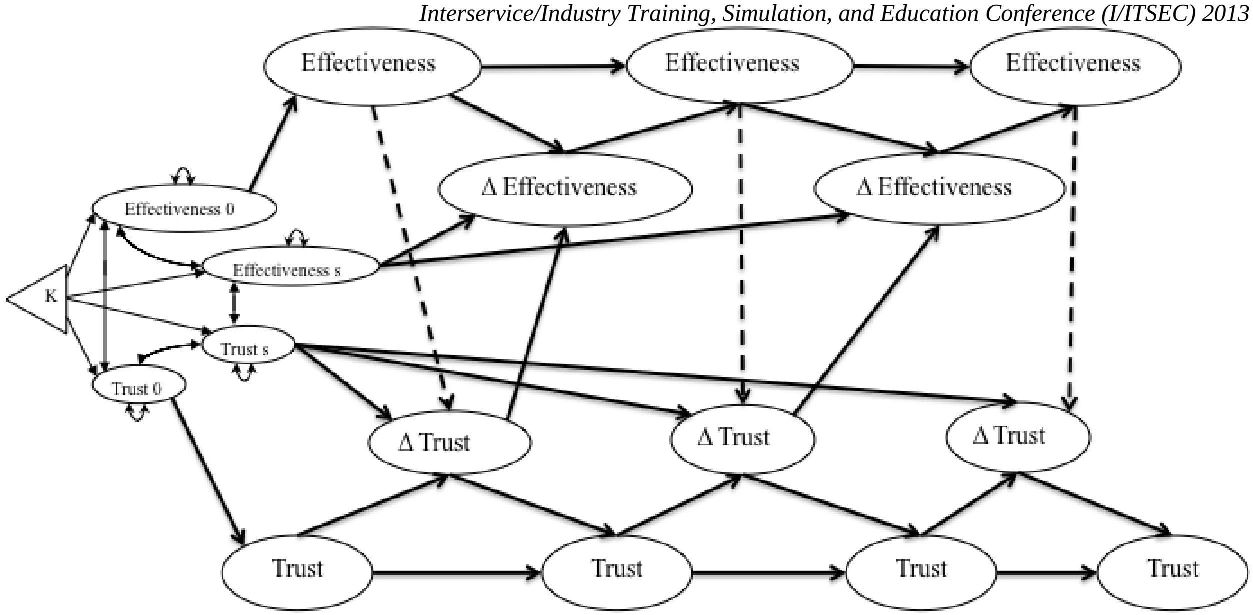

Figure 1. The constructs in a latent change model for the relationship between effectiveness and trust over time. The alternative model does not include the parameters indicated by the dashed lines between effectiveness and change in trust. Measured variables are left off for clarity of presentation. The five left-most constructs represent the latent slopes (s) intercepts (0) and constant (K).

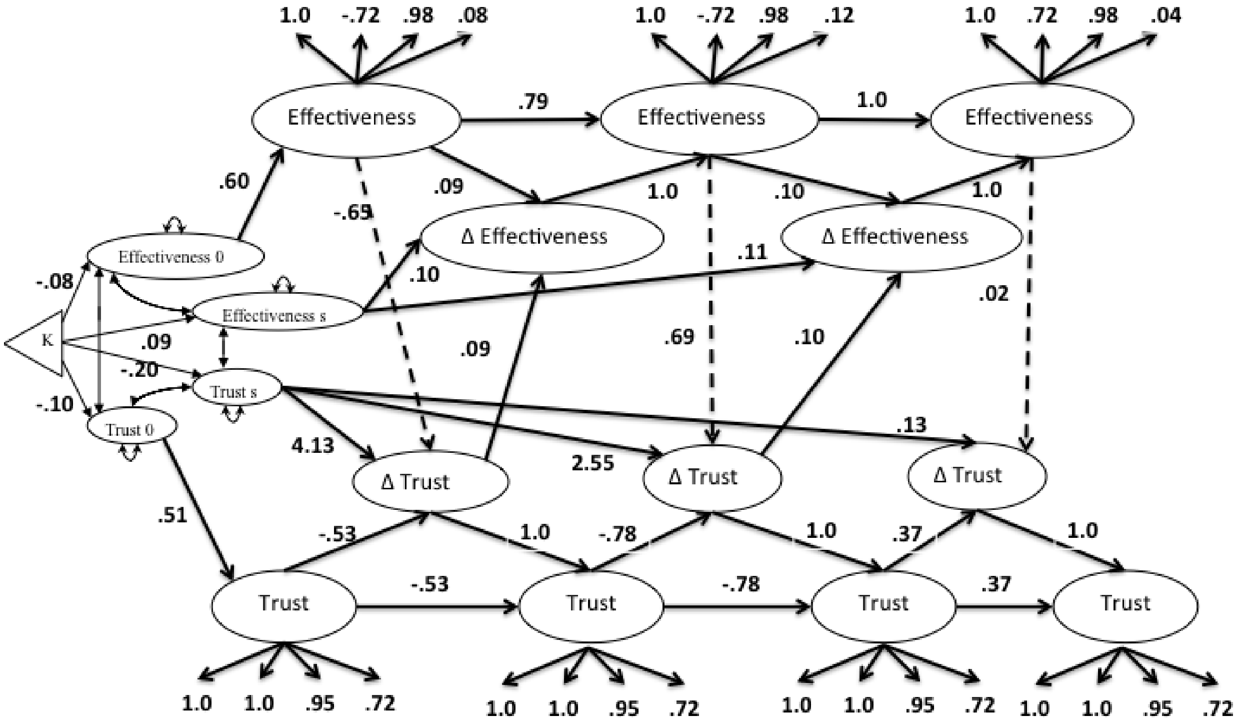

Figure 2. Parameter estimates for the latent change score model specifying the relationships between effectiveness and trust over time. Consistent with the LCS framework, factor loadings for trust and effectiveness latent variables are constrained to be invariant across occasions. Measured variable error estimates are not reported for clarity of presentation.

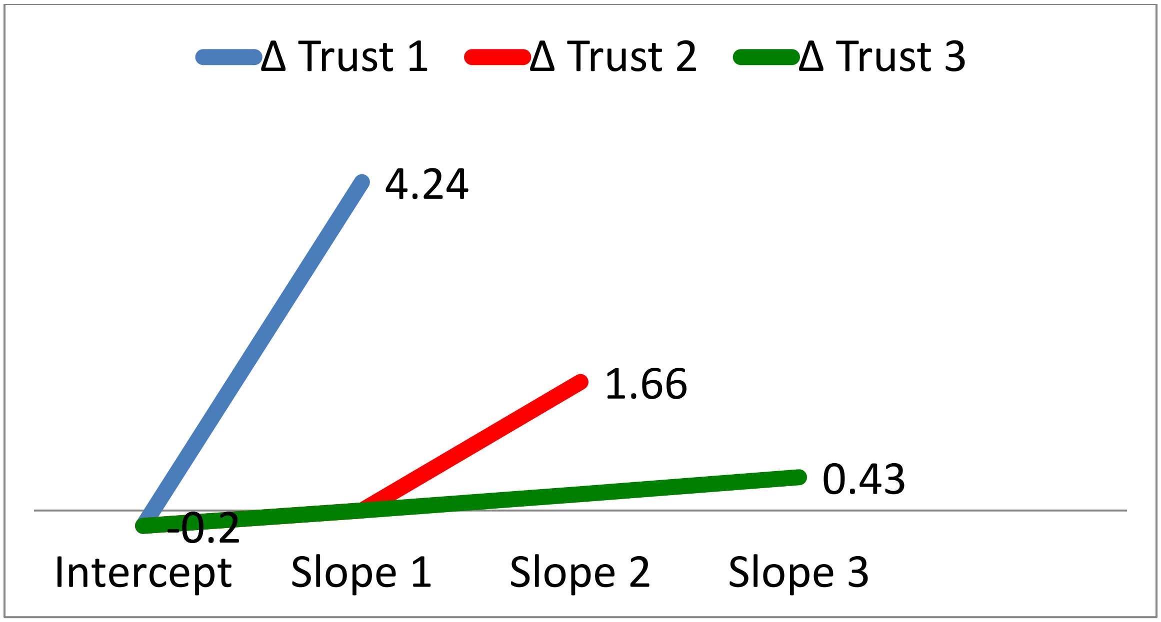

Figure 3. Slopes for the differential rates of change in trust for the three change scores of trust.

DISCUSSION

Our work addresses several issues important for understanding how trust evolves in distributed teams. We have described and demonstrated how a latent change score methodology is useful for obtaining parameter estimates for models of theoretical and practical importance. We independently modeled two types of trust as it evolved over time and examined the interplay of effectiveness on change in trust. We also show that the rate of change in trust varies over time, with the greatest amount of change occurring early and decreasing progressively over time (slope=4.24, 1.66, and .33 for change time 1, 2, and 3, respectively).

With both cognitive and affective trust models working well, we have demonstrated support for these theoretical perspectives. Practitioners should be attuned to the process whereby cognitive and affective trust influence individual behavior, and should maximize attempts to influence it.

It appears clear that effectiveness impacts the change in trust. The nested model comparisons show that the parameters are adding additional explanatory capability to the models. Additionally, we see that the role of effectiveness in influencing change in trust is more important at the early and midpoints of goal-oriented team activities. This implies that organizations should structure work so the teams have early successes, thereby increasing the likelihood and rate of trust development.

Finally, it is important to attend to the fact that rates of change in trust are highest early on. The rate of change at the first point in time is over two and a half times the rate at the second change point, and nearly ten times the rate of change at point three. Similarly, the rate of change at time two is nearly four times greater than it is at time three.

This research demonstrates that trust develops in a non-linear fashion over time. This is likely due, at least in part, to the technological medium. In order to fully examine the effect size of technology on trust it would be necessary to conduct a study that directly compared technologically medicated versus non-mediated teams.

CONCLUSION

Researchers have long understood the importance of trust in team effectiveness. Little has been explored, however, on how trust develops in distributed teams who rely on technology to communicate. The increasing reliance on technology-mediated communication in the workplace makes it imperative to understand the processes through which distributed teams develop trust. Using affective and cognitive-based models of trust, this study sheds further light on this issue, and points to the importance of distributed teams performing successful tasks at an early stage in their development in order to facilitate levels of trust.

Implications from this work for military applications are quite strong. As we look for ways to increase the readiness and resilience of our forces before during and after combat, ensuring that the nature of the work and the tasks we expect teams to do in training and in operations, are similar to one another. Moreover, in a team training context we can structure the team tasks in ways to not only accomplish the important mission training, but to also ensure early successes for the team in training. Based on the results of the present study, the potential for obtaining higher levels of trust in training is very good and the longer term transfer of that high level of trust to operational team performance is equally good. Additional research is being planned to leverage the results from this study and being to develop operational analogues of the experimental task so that we can being to explore and evaluate interventions to promote team trust and performance success in training, and then to track team trust and performance into operational settings. Further down the road, there may even be opportunities to redesign work and our concepts of operations based on better ways to foster trust and improve team process and performance.

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