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RESEARCH NOTE

Trust of an Automatic Ground Collision Avoidance Technology: A Fighter Pilot Perspective

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The present study examined the antecedents of trust among operational Air Force fighter pilots for an automatic ground collision avoidance technology. This technology offered a platform with high face validity for studying trust in automation because it is an automatic system currently being used in operations by the Air Force. Pilots (N = 142) responded to an online survey which asked about their attitudes toward the technology and assessed a number of psychological factors. Consistent with prior research on trust in automation, a number of trust antecedents were identified which corresponded to human factors, learned trust factors, and situational factors. Implications for the introduction of novel automatic systems into the military are discussed.

Keywords: trust in automation, automatic ground collision avoidance system, trust, aviation psychology

Military fighter operations are highly complex and dangerous, yet they are essential to the National defense. Evidence of their complexity can be found in the fact that controlled flight into terrain (CFIT) remains a significant problem for the U.S. Air Force (Richardson, Eager, & Hamilton, 2015). CFIT occurs when a "healthy" aircraft crashes into the ground because the pilot becomes spatially disoriented and loses awareness of the ground or because the pilot experiences gravity-induced loss of consciousness. To address and potentially mitigate the precursors of CFIT, the Automatic Ground Collision Avoidance System (AGCAS) was created as an automatic technology to support pilots. Fielded in 2014 on the F-16 platform, AGCAS is an automated technology that (a) assumes control of an aircraft when it detects an imminent collision with the ground, (b) initiates a rapid fly up maneuver to vector the aircraft away from danger, and (c) returns control to the pilot after the collision is thwarted (Richardson et al., 2015). AGCAS has perhaps

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the highest level of autonomy for safety systems in service to date, and as such, it represents an excellent platform for the study of trust in automation. The present study will report the results of an applied survey of Air Force F-16 pilot's trust of AGCAS.

The Department of Defense (DoD) has long leveraged advances in technology to support the increased use of automation within military contexts (Endsley, 2015). Researchers in recent years have discussed the importance of trust in the context of automated systems given the potential issues associated with miscalibrated trust (Chen & Barnes, 2014; Lee & See, 2004). In fact, a number of accidents involving both under trust and over trust have been documented in the literature (Hoff & Bashir, 2015). Trust represents one's willingness to be vulnerable to another entity without having proper controls in place to monitor the behavior of the other entity (see Mayer, Davis, & Schoorman, 1995). In the context of technology, the willingness to be vulnerable involves decisions to rely on technology, and at times, humans make suboptimal reliance decisions resulting in performance errors. Optimal trust of the AGCAS platform is important because if pilots trust the system too much, they may engage in riskier flight patterns knowing the system will protect them; whereas too little trust may result in pilots not using the system to its full potential by switching it off or flying more conservatively (Lyons et al., 2016). AGCAS offers a superb platform for studying trust in automation because (a) the vast majority of trust in automation studies have utilized laboratory tasks while AGCAS is an operational system embedded on complex military aircraft—thus, it should convey high ecological validity, (b) the tradeoffs for trust of AGCAS have very real implications for pilots—thus this study has high applicability to applied DoD needs, and (c) AGCAS is a relatively new technology fielded as recently as 2014—thus, it offers a unique perspective to isolate the predictors of trust for a novel automated system and to track the evolution of pilot trust over time.

Recent research has revealed three categories of antecedents for trust in automation: human factors such as individual differences, preferences, and workload; situational factors; and learned trust factors such as the system's performance, error types, experience, and anthropomorphic features (Hoff & Bashir, 2015). The current study sought to reveal the antecedents of pilot trust of AGCAS by assessing a variety of psychological constructs such as: automation schema (individual difference variable); perceived reliability, transparency, and benevolence (learned trust characteristics); and perceived benefits (situational variable) and their association with trust among operational fighter pilots.

Reliability

The performance of an automated system has been shown to be a robust predictor of trust among users of the systems (Hancock et al., 2011; Hoff & Bashir, 2015). Systems that perform better and demonstrate high reliability are trusted more than those that evidence poor performance. In the case of AGCAS, one of the most significant performance issues is the ability of the technology to avoid nuisance activations, which would be considered as akin to a false alarm (Lyons et al., 2016). The literature on trust in automation has consistently demonstrated that errors, false alarms in particular, can have a degrading effect on trust (Geels-Blair, Rice, & Schwark, 2013).

> *Hypothesis 1:* Reliability perceptions will predict higher trust.

Transparency

As technology becomes increasingly capable and is afforded more decision authority, the notion of transparency will be an important antecedent of trust. Transparency methods help to establish user awareness and knowledge of the system and explain how/why it operates in certain ways. Systems should be designed to foster user awareness of the current and future state of the system as well as the intent of the system (Chen & Barnes, 2014). Thus, transparency manipulations might target how, why, and when a system like AGCAS operates. AGCAS was designed with a heads-up display to communicate to the pilots when an AGCAS activation is imminent and this information has shown to foster trust among test pilots (Lyons et al., 2016); yet it is unclear how this will affect nontest pilots. Greater awareness of when and why activations occur should be related to higher trust.

> *Hypothesis 2:* Transparency will predict higher trust.

Benevolence

A key antecedent to trust is the notion of whether or not the target of one's trust has the trustor's best interests in mind (i.e., benevolence; Mayer et al., 1995). Benevolence is one of three primary trust antecedents along with ability and integrity discussed by Mayer and colleagues (1995) in their seminal trust model. AGCAS was designed to reduce CFIT, and it does this on the behalf of the pilots. As such, the pilots' understanding of this intent by the developers of the system should be important for the pilot's trust of the system.

> *Hypothesis 3:* Benevolence perceptions will predict higher trust.

Benefits

The introduction of technology does not occur in a vacuum. In fact, there are often cost–benefit tradeoffs that exist with the introduction of novel automatic technologies, and often these tradeoffs are difficult to analyze as the introduction of automation can lead to unintended consequences (Parasuraman & Riley, 1997). Organizations can insert novel technology into operations with the hope and objective of improving performance, however, if the employees perceive that the costs of engaging with the new technology are high, then the employees may neglect to use the novel technology. In fact, researchers have estimated that approximately 80–90% of newly introduced technology in the workplace fails to meet its strategic objectives, largely due to factors such as mismanaged expectations among the target users groups (Clegg et al., 1997). Thus, common-sense perceptions and beliefs among user groups (e.g., Will this technology help me? Will this technology be too difficult to use?) will shape initial behavior related to novel automated tools. When considering one's initial trust of a novel system, the perceived benefits of using the technology will be an important determinant of one's trust of the technology (Li, Hess, & Valacich, 2008). Logically, higher perceived benefits of using the technology should foster greater trust.

> *Hypothesis 4:* Perceived benefits of AGCAS will predict higher trust.

Automation Schema

Individual differences remain a fruitful domain for understanding how individuals will or will not trust automation (Hoff & Bashir, 2015; Merritt & Ilgen, 2008; Merritt, Unnerstall, Lee, & Huber, 2015). By isolating the impact of individual differences on trust one might be better able to anticipate how individuals will react to a novel technology. Merritt and colleagues (2015) have developed measures to gauge one's level of perfect automation schema, a cognitive belief related to the performance of automated systems. A high level of perfect automation schema would be characterized by the belief that a technology is infallible, such as when an individual might never question the validity of a global positioning system device. In contrast, individuals low on automation schema view technology with an eye of skepticism. Recent research has found that when individuals have high expectations of technology, they are more aware of changes in the reliability of the technology (Pop, Shrewsbury, & Durso, 2015). Further, higher perfect automation schema has been linked to higher levels of trust of automated systems (Merritt et al., 2015).

> *Hypothesis 5:* Automation schema will predict higher trust.

Confidence

Trust in AGCAS should relate to higher confidence perceptions in one's ability to fly. While much of the trust in automation literature has looked at self-confidence for manual control as a factor in shaping reliance on automation (see Hoff & Bashir, 2015; Moray, Inagaki, & Itoh, 2000), the current study looked at confidence as an outcome variable of interest. Lyons, Stokes, Eschleman, Alarcon, and Barelka (2011) used confidence as an outcome measure and found that trust in an automated decision aid was related to decision confidence. We predicted a similar relationship in the current study.

> *Hypothesis 6:* Trust will be positively related to pilot confidence in their ability to fly.

Method

Participants and Procedure

Operational F-16 pilots (N = 142) from 10 different Air Force bases (eight active duty and two Air National Guard) participated in a survey that evaluated their trust of AGCAS. The pilots averaged 45 sorties (SD = 25) with an AGCAS-capable F-16 over the course of the first approximately 6 months of its implementation. While the number of sorties with an AGCAS capable aircraft may seem low, it is an accurate reflection of pilot experience level with AGCAS at the time of the survey because AGCAS was fielded in 2014. Neither the number of flight hours in the F-16 nor the number of sorties with an AGCAS-capable aircraft was related to trust; thus, neither was used as a control variable in the subsequent analyses. Pilots were invited to participate in an online survey by their safety officer or their unit commander via e-mail. The e-mail included a link to the survey items that was hosted on a secure server, and all of the items discussed herein used 7-point Likert scales ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Measures

Trust. Four items were used to assess trust. Given the low base rate for system activations (i.e., fly ups) in the case of AGCAS,[1] trust was operationalized as the pilots' ability to "count on" AGCAS to operate when it needed to rather than using actual activations as a means to benchmark trust. Because the rate of actual activation experience was so low, the authors felt that gauging trust in relation to actual activations would have been challenging for pilots who have never experienced an AGCAS activation, which, in this case, would have been 88% of the sample. Additionally, operational pilots typically do not have access to AGCAS in a simulator. Most operational pilots do however, report seeing the chevrons on the heads-up display during operational or training flights, which signals that the system is working. Example items included, "I can count on AGCAS to work when needed" and "I can count on AGCAS to work during combat."

Reliability. The reliability of AGCAS was measured using four items that tapped into pilot perceptions of how well the system performed. The items were "Auto-GCAS is reliable," "AGCAS is designed in such a way to minimize nuisance to the pilot," "AGCAS does not interfere with my ability to fly," and "AGCAS effectively prevents CFIT."

Transparency. Three items were used to assess how well pilots understood the analytical underpinnings of the system. The items were "I understand how Auto-GCAS works," "I understand how AGCAS senses the environment," and "I understand when AGCAS will activate."

Benevolence. Benevolence was assessed with three items. They were "I think Auto-GCAS was designed to help me," "I understand the purpose of AGCAS," and "AGCAS was designed with my best interests in mind."

Benefits. Perceived benefits were measured with two items, "I benefit from having Auto-GCAS installed on my plane" and "Other pilots benefit from having AGCAS installed on their planes."

Automation schema. Automation schema was assessed using three items developed by Merritt and colleagues (2015) to measure high expectations of automation. The items were "Automated systems rarely make mistakes," "Automated system have 100% perfect performance," and "Automated systems can always be counted on to make accurate decisions."

Confidence. Pilot confidence was assessed using three items. Items included "I feel more confident flying with Auto-GCAS installed on my plane," "I feel confident Auto-GCAS will protect me if I experience spatial disorientation, G-induced loss of consciousness (G-LOC), or loss of consciousness," and "How comfortable are you with Auto-GCAS automatically take control of the aircraft?"

[1] At the time of the survey, approximately 12% of the pilots had reported experiencing an AGCAS activation.

Results

As shown in Table 1, all of the scales evidenced moderate to high reliability. Reliability, transparency, benevolence, benefits, and automation schema were all positively related to trust, providing initial support for all of the hypotheses. However, given that some of the predictors were correlated, multiple regression analysis was used to parse out the unique predictors of trust. As shown in Table 2, only reliability, benefits, and automation schema each had a positive relationship with trust, while transparency and benevolence did not. This provides support for Hypotheses 1, 4, and 5 and fails to support Hypotheses 2 and 3. As shown in Table 1, trust was positively related to confidence, supporting Hypothesis 6.

Table 2
Multiple Regression Analysis for Reliability, Transparency, Benevolence, Benefits, and Automation Schema as Predictors and Trust as the Criterion

	Trust	
Predictor	β	R^2
		.47**
Reliability	.39**	
Transparency	.10	
Benevolence	.06	
Benefits	.25**	
Automation schema	.13†	

† $p < .10$. ** $p < .01$.

Discussion

The current research sought to understand the antecedents of trust among operational F-16 pilots for the Air Force's Automatic Ground Collision Avoidance System, a highly automated safety system recently fielded on the F-16 platform. This research was motivated by the dearth of field studies for trust in automation using actual automated systems within the military. The results are largely consistent with the literature on trust in automation and are briefly discussed below. It was expected that reliability, transparency, benevolence, perceived benefits, and automation schema would all be related to higher trust. While each variable had a significant positive relationship with trust, only reliability, perceived benefits, and automation schema evidenced a unique prediction of trust when the set of predictors was evaluated as a set. While it is surprising that transparency and benevolence did not uniquely predict trust it is encouraging that, consistent with a recent review of the trust in automation literature (see Hoff & Bashir, 2015), a diverse set of predictors was found in an applied sample evaluating a fielded technology.

Reliability has consistently been shown to be a predictor of trust in a human-machine context (Hancock et al., 2011; Lee & See, 2004), so the present results continue to demonstrate the importance of system reliability on trust. One's perceived benefits from using a novel technology also appear to be a reliable trust antecedent in this applied sample. This is consistent with prior research on technology introduction/adoption (Li et al., 2008). Individual differences in the form of automation schema (Merritt et al., 2015) seem to be a driver of pilot trust of AGCAS. It is possible that the very high means for transparency and benevolence may have created a ceiling effect limiting the predictive variance of those variables on trust. Finally, consistent with prior research (Lyons et al., 2011), trust was positively related to

Table 1
Descriptive Statistics for All Study Variables

Variable	*M* (*SD*)	1	2	3	4	5	6	7
1. Trust	5.50 (1.10)	.94						
2. Reliability	5.72 (.91)	.63**	.72					
3. Transparency	6.08 (.65)	.23**	.25**	.82				
4. Benevolence	6.35 (.86)	.43**	.53**	.36**	.69			
5. Benefits	6.34 (.86)	.55**	.62**	.05	.58**	.86		
6. Automation schema	2.51 (.98)	.29**	.27**	.07	−.02	.18*	.66	
7. Confidence	5.48 (1.05)	.68**	.56**	.13	.45**	.65**	.38**	.66

Note. Reliability coefficients are provided on the diagonal.
* $p < .05$. ** $p < .01$.

pilot's confidence. This finding is useful as researchers continue to explore the outcomes of trust in automation in applied settings.

Implications

The current results suggest that as DoD organizations develop and transition novel technology to military operators they should consider integrating trust-based information related to the system into the marketing and training for the system. Marketing campaigns should focus on the benefits of the system. Training programs should foster opportunities for operators to understand the true reliability of the system. Note, however, that operators should not be deceived into thinking that a system is more capable than it truly is as that could foster complacency and ultimately result in performance errors (Parasuraman & Manzey, 2010). Operational pilots might first experience AGCAS in a simulator to get familiar with the system and its behavior. This opportunity during simulation could be an invaluable opportunity for the pilots to test the boundaries of the technology in a safe manner. Trainers and supervisors should also be sensitive to individual differences among their personnel that might bias them positively or negatively toward or away from novel technology. While not uniquely predictive in the present study, training (i.e., to foster skills and knowledge through structured practice) and marketing messages for novel DoD technology should also provide the decision logic and analytical underpinnings of the system (i.e., transparency) as well as the design rationale/business case for the technology (i.e., benevolence in the present study).

Limitations

The current study has a few notable limitations. First, the sample understudy involved military personnel using a military technology. It is possible that the results discussed herein, while useful for a military context, may not generalize to the civilian sector. Military personnel are a unique population with different training, missions, and esprit de corps relative to the civilian population. However, AGCAS may, at a conceptual level, fulfill a similar function as modern driver assistance systems (Inagaki, 2008), and as such, civilians will be forced to evaluate their trust of similar systems—albeit at a lower level of complexity. Second, some of the measures used in the current study evidenced questionable reliability. While the impact this low reliability would be attenuate versus strengthen relationships among variables (Bobko, 2001) the current results should be viewed with caution. Future research should incorporate a variety of methods that leverage the richness of field environments to garner additional insight into the adoption, maintenance, and termination of technology in operational environments.

Conclusions

The current research examined the predictors of trust for a complex automated system recently fielded within the Air Force. The results were consistent with contemporary models of trust in automation supporting the joint role of individual differences, learned trust factors, and situational factors. This research extends trust in automation literature by demonstrating the utility of multiple trust antecedents using real operators and a very real technology with high-consequence implications for the trust process.

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