Using System-wide Trust Theory to Analyze Passenger Loss of Trust in Aircraft Automation

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ABSTRACT

The current study focuses on airline passengers and how they might be affected by the contagion of an unreliable automated device. Participants took part in an online survey where they were presented with a scenario in which they were on an airline flight and oxygen masks erroneously dropped from the compartment above. They were then asked to rate their trust in that automated device, along with four other unrelated devices (auto-pilot system, flaps, landing gear, and video screen). In a control condition, no error occurred with the oxygen masks, and trust was high for all automated devices. In the experimental condition, trust was lower for all automated devices. In fact, in most cases, trust in the other automated devices dropped nearly as much as it did for the unreliable device. These results show that system-wide trust theory can make accurate predictions about the contagious effects of unreliable automated devices on otherwise unknown or reliable devices for non-expert airline passengers. This provides evidence that people tend to: a) view different automated components of an aircraft as part of a system even when they are logically independent of each other; and b) distrust other components of that "system" when one component fails.

Keywords: System-wide trust, trust in automation, consumer perceptions, airline passengers, reliability

INTRODUCTION

Background

Previous research has been conducted looking at operator's trust in automated devices while completing a task testing the system-wide trust (SWT) theory. The research looked primarily at how the operator interacted with one automated aid known as a single-device paradigm (Dixon & Wickens, 2006; Dixon, Wickens, & Chang, 2005, Dixon, Wickens, & McCarley, 2007; Geels et al., 2011, Keller & Rice, 2010; Lee & Moray, 1994; Parasuraman, Sheridan, & Wickens, 2000; Rice, 2009; Rice & Geels, 2010; Rice et al., 2008; Wickens & Colcombe, 2007; Wiegmann, Rich, & Zang, 2001). In more recent studies (Geels-Blair, Rice, & Schwark, 2013; Keller & Rice, 2010; Rice & Geels, 2010), there was a shift from looking at single-device paradigms to encompass multiple devices, and it revealed a system-wide trust effect. In other words, it was concluded that operators group multiple aids together into a single system, and when one device in the system is unreliable, the operator treats the entire system as unreliable.

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This study seeks to examine consumer views toward automation trust using European participants via an online survey. The adverse effect found with multiple aids and operators is hypothesized to occur with *consumers* when examining commercial airplanes. Instead of real-life experiences, participants were given scenarios to reveal a SWT effect in consumers. In one scenario, there was a failure of an automation system and the experimental group was asked to rate their trust in other, non-relevant automated aids. The control group received the same scenario, but it did not include the failure of an automation system.

A discussion on trust in automation will be examined in the following sections, and an explanation of system-wide trust will be provided. These sections will illustrate the need for the current study and offer more information about the implication of system-wide trust theory on consumer perceptions.

Automation

The definition of automation (Wickens & Hollands, 2000) is a mechanical or electrical task of work that would usually be completed by a human operator. The four stages of automation include synthesis, diagnosis, response selection, and response execution (Parasurman, Sheridan, & Wickens, 2000). When a task is unsuitable for a human to undertake, automation can be a valuable asset in assisting a human operator to complete a task. For example, when monitoring multiple gauges for an extended period of time, automation can help relieve some of the workload (Bainbridge, 1983). As convenient as automation can be, it is by no means a perfect system. When false alarms (FA) and misses occur, it can lead to mistrust in the automation system, or worse, completely ignoring the system.

When an automation system alerts an operator to a condition that does not actually exist, that is referred to as a false alarm. Alternatively, misses occur when the automation fails to notify the operator of a condition when there is an event. One or the other of these situations can impact the operator's trust in automation (Geels-Blair, Rice, & Schwark, 2013; Parasuraman & Riley, 1997; Rice, 2009; Rice & Geels, 2010). In regards to previous research, misses and false alarms have been seen to drag down operator trust in the device with the condition present, but also in unrelated automated devices.

Trust

In social psychology, trust is defined as the predictability of another person (Deutsch, 1958; Eckel & Wilson, 2004; Ergeneli, Saglam, & Metin, 2007), and through research it has been determined that this concept can be related to automation (Reeves & Nass, 1996; Rice, 2009; Parasuraman & Riley, 1997). Humans interact on a daily basis and with trust, humans can predict what a person is expected to do. A high level of trust equates to how a person believes that another person will do what is expected, and generally it will be a positive interaction (Lee & See, 2004). Human interactions can be extrapolated to include how humans interact with machines. In other words, trust can be interrelated to human-machine interactions (Geels-Blair, Rice, & Schwark, 2013). The current study was interested in how trust varies when devices fail or do not operate as anticipated by the consumer.

In the past few decades, there has been technological advancements and along with that, an increased use of automation. However, there is often an added level of complexity with the introduction of automation. Individuals use trust to help adjust to the complexity by augmenting supervision. This helps reduce uncertainty and therefore, reliance is guided by trust in automation. It is impractical to assume that a complete understanding in a situation is possible, but using trust and reliance, individuals can adapt to the situation and deal accordingly with automation (Lee & See, 2004). Automation failure is a key feature that researchers are eager to understand, especially in the context of multiple automated aids (Keller & Rice, 2010; Rice & Geels, 2010).

Previous research has examined how operator's trust level changes depending on the reliability of the automated aid. A positive relationship has been observed, which means that if the operator has a high level of trust, they will rely on the aid (Rice, 2009). Additionally, operators appear to view unrelated automated aids as one system (Geels-Blair, Rice, & Schwark, 2013; Keller & Rice, 2010; Rice & Geels, 2010) instead of treating an unreliable device on its own. This demonstrates that operators treat the entire system as unreliable and provides support of system-wide trust theory.

System-Wide Trust Theory

In earlier research, single-aid paradigms where the primary focus of automation trust (Maltz & Shinar, 2003; Meyer, 2001, 2004; Rice, 2009). This meant that operators were only paired with a single automated device. Keller and Rice (2010) embarked on a study to look at whether participants had component-specific or system-wide tendencies of trust when using multiple aids. In a component-specific perception, operators would differentially place their trust in different devices. To elaborate, an operator would be able to discern the reliability differences between two aids and treat only the faulty aid as such and continue to trust the other reliable aid. The system-wide view occurs when an operator is unable to treat various aids as independent entities. In other words, if one of the aids is unreliable, then it adversely affects the level of trust the operator has towards the other unrelated, reliable aids.

To test these two theories, a simulated flight test was used. In the experiment, the operator was assigned to fly an unmanned aerial system (UAS) and check for system errors in two gauges that were positioned below the screen (Keller & Rice, 2010). In each condition, the percentage of reliability varied by 100%, 85%, or 75% reliable. It was solely up to the operator to agree or ignore the aid. It was apparent that by the end of the study, the data pointed to a system-wide trust of automation aids. The research showed that one unreliable aid could adversely affect the trust in the reliable aids (Keller & Rice, 2010). The limitation in this research study was the use of only two gauges, which caused the unreliable aid to represent 50% of the system. Another limitation included that there was not a large pool of participants, and all were from the subject university.

A later study included four gauges, which increased the ratio of perfect to imperfect aids from 1:1 to 3:1 (Rice & Geels, 2010). A single-task paradigm was used to help avoid confounding dual-task variables. Misses were examined in this study instead of false alarms, to see if the same effect would occur. By the end of the experiment, the results coincided with the earlier study. Even when the participants were given accurate and detailed information about the reliability of each automated aid, they still succumbed to the effects of system-wide trust. The same demographic limitation was present with a low participant pool as the previous experiment.

Geels, Rice, and Schwark (2013) continued research along these lines, but instead utilized eight gauges and compared the adverse effect that false alarms and misses had over the operator's trust. Of the eight gauges, one was either 100% or 70% reliable, and included either false alarms or misses. The data shows that regardless of the number of automated aids used in the experiment, participants still grouped aids together. These findings support system-wide trust theory. When comparing false alarms and misses, false alarms correlated with a stronger system-wide trust effect. This study had a larger sample pool, but the demographics of the participants were still limited to the subject university.

METHODS

Participants. Ninety-eight (30 females) participants from European countries took part in the study via an online survey. The mean age was 30.42 (*SD* = 9.57).

Materials and Recruitment. The study was presented online using FluidSurveys ®. Participants were recruited via Amazon's ® Mechanical Turk ® (MTurk). MTurk is a global online service that enables participants (Turkers) to participate in Human Intelligence Tasks (HITs) in exchange for monetary compensation. Participation in any HIT is voluntary and anonymous.

Procedure. Participants first signed an electronic consent form. They were then presented with the following scenario: "*Imagine that you are flying on a 4-hour commercial airplane flight from one major city to another. Sometime during the flight, an alarm goes off throughout the cabin and oxygen masks fall from the compartments above passenger seats. Following this, the pilot comes on the intercom and says that there was a mistake and the automation that operated the oxygen masks failed. He says that there is no actual emergency and not to worry. The pilot then tells you the altitude of flight and how long it will be before you land.*" In a separate control condition, participants were given the same scenario without the failed oxygen mask situation.

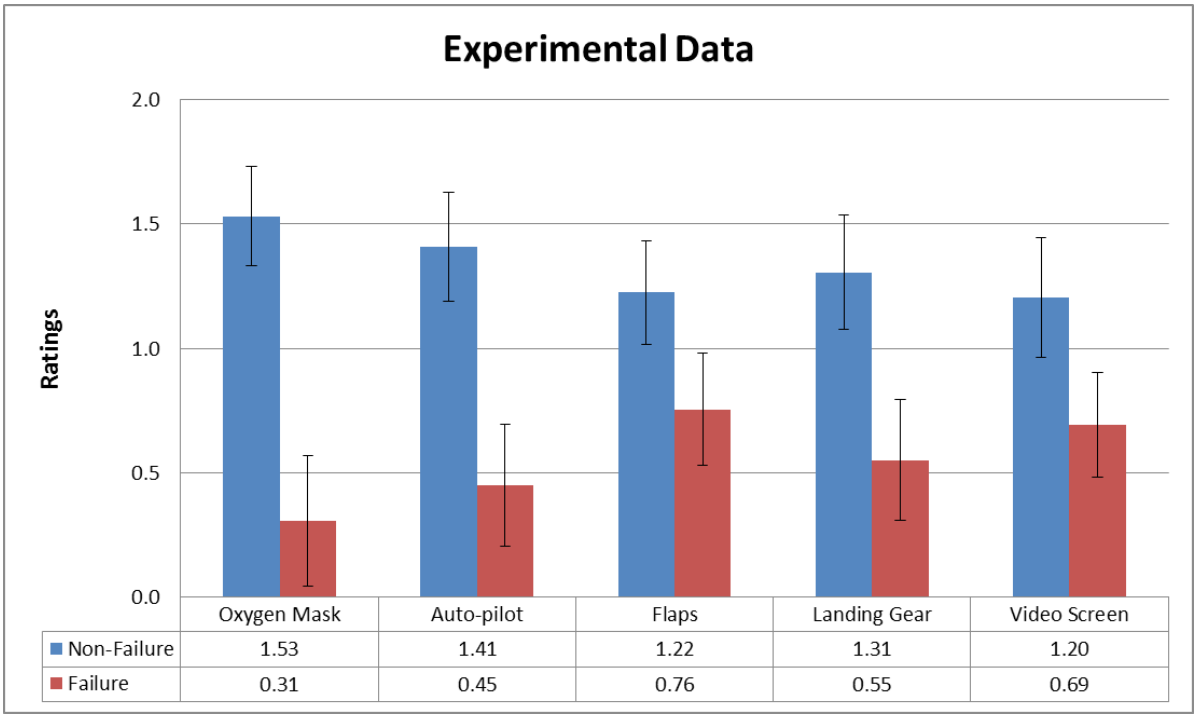
Participants were then asked to rate their trust in the automation that operates the oxygen masks, auto-pilot system, airplane flaps, landing gear, and seat video monitor on a Likert-type scale from -3 (extremely distrust) to +3

(extremely trust) with a neutral option of zero (neither trust nor distrust). Following this, participants were asked to provide demographic information and were then dismissed.

Design. A mixed design was employed with different participants in the experimental and control conditions, and all participants providing ratings for all the different automated devices.

RESULTS

Figure 1 presents the data from the study. A two-way 2 x 5 analysis of variance (ANOVA) was performed on the data, with FailureNonfailure being the between-participants condition and TypeofAutomation being the within-participants condition. There was a marginally significant interaction in the data, $F(4, 384) = 2.22$, $p = .066$, $\eta p^2 = .02$. The main effect of FailureNonfailure was significant, $F(1, 96) = 9.21$, $p = .003$, $\eta p^2 = .09$, indicating that trust in the automated devices were lower in the failure condition compared to the non-failure condition. The main effect of TypeofAutomation was not significant, $F(4, 384) = 0.07$, $p = .99$, $\eta p^2 = .001$.



	Oxygen Mask	Auto-pilot	Flaps	Landing Gear	Video Screen
Non-Failure	1.53	1.41	1.22	1.31	1.20
Failure	0.31	0.45	0.76	0.55	0.69

GENERAL DISCUSSION

The purpose of this study was to examine the effects of SWT theory on consumers in a commercial aviation setting. The unique piece of this experiment was the investigation of consumers instead of operators. Participants were from European countries, placed in either a control or experimental condition, and then were asked to rate their trust level in automated aids. In the experimental group, a failure of an automated aid was present, while this was restricted with the control group. The findings of the study support the hypothesis set forth by the authors that, like operators, consumers would follow a system-wide trust process.

The current study found that participants rated non-related automated aids as less reliable when paired with a failed automated device, and there was evidence that the SWT effect caused lower trust ratings across all automated devices. The main effect of FailureNonfailure was significant, which indicates that consumer's trust in automated devices was lower in the failure condition compared to the non-failure condition. This supports the finding that consumers gage their trust in the system as a whole. It would seem that consumers have a difficult time differentiating between separate, independent components when it comes to failures. Also, it is, to some extent, illogical for consumers to presume that the failed component is related to the other components. These results are uniform with the findings from previous research, which had focused on operators (Geels-Blair, Rice, & Schwark, 2013; Keller & Rice, 2010; Rice & Geels, 2010). These results are interesting since consumers do not usually have as much information as operators.

Practical Implications, Limitations, and Recommendations

The findings from this study pose some interesting practical implications. The data demonstrates that there was a reduction in consumer's trust level of automated devices. This concept of system-wide trust could greatly influence participants' views of the safety of commercial aircraft. If analyzed from a business perspective, then it may translate to consumers seeking the service of a different airline entirely. Every day the news is full of stories surrounding issues like the batteries found in Boeing's 787 Dreamliner. Does this make consumers less trusting of the other functions of the Dreamliner or of Boeing as a company? This is an area that requires more research to identify the impact that these issues may have on consumers.

Severity of the incident could likely influence this decision as well. The main limitation of the current study is that it was unable to be executed in a real-world setting. Given the findings from previous research concerning operators, it can be assumed that this particular limitation would not pose a serious threat to the findings of this study. Further research would be needed to check the validity of this assumption and the findings of this study.

CONCLUSIONS

System-wide trust theory suggests that individuals are unable to accurately differentiate between trust in failed and non-failed automated components. Earlier studies have examined trust in automation using both single and multiple aids. Initially, research focused on the response of operators or those trained in the functionality of the systems. These studies all found that a system-wide trust view was present, and operators rated all automated devices as less trustworthy despite little logical explanation. In the current study, *consumers* were asked to rate their trust in automated components during a scenario where they were a passenger on a commercial aircraft flight. The findings of this study seem to replicate those of earlier studies. Passengers in the experimental group that received the failure of an automated device rated their trust in other unrelated automated aids as less than a control group that did not receive a failure. As with earlier research, these findings support that consumers are also likely to use a system-wide trust theory in their interpretation and trust of automated commercial aircraft components.

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