ASSOCIATIONS BETWEEN TRUST AND PERCEIVED USEFULNESS AS DRIVERS ADAPT TO SAFETY SYSTEMS

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ABSTRACT. Drivers' acceptance and reliance on technology that mitigate driver distraction depends on several factors including trust. Feedback regarding the degree of distraction can be provided in real-time or as post-trip information. Subjective ratings of trust were collected to assess the influence of these different feedback types in a driving simulator study in which drivers interacted with a distracting secondary task. The results suggest that trust changes over time and that this change is associated with acceptance of feedback, in particular its perceived usefulness. The timing of feedback did not have a significant impact on trust; however drivers generally trusted both feedback timings with males trusting feedback more than females. Understanding how trust develops in the various forms of feedback can provide designers with information to enhance the driver-vehicle interface and to better mitigate the effects of distraction.

INTRODUCTION

A driver's response to technology is driven by many complex factors and understanding them is the cornerstone for developing effective and user-accepted safety systems (Naatanen & Summala, 1974). Studies have identified many factors that relate to safe driving (e.g., weather, vehicle characteristics, driver demographics and cognitive ability) (Anstey, Wood, Lord, & Walker, 2005; Chang & Mannering, 1999; Desai, Ellis, Wheatley, & Grunstein, 2003; Lundberg, Hakamies-Blomqvist, Almkvist, & Johansson, 1998). However, drivers' adaptation to these systems and its influence on their safety has not been as well understood. Adaptation as influenced by the immediate change in the system as well as long-term perceptions based on system exposure is a significant contributor to the overall safety outcome.

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Driver distraction is a growing concern as in-vehicle devices become more common. Several studies have demonstrated the detrimental effects to safety of various types of distractions (Hancock, Lesch, & Simmons, 2003; Harlbluk, Noy, Trbovich, & Eizenman, 2007; Neyens & Boyle, 2007). Drivers may even adapt to the distracting effects in unintended ways such as increasing their headway distance while using the in-vehicle system (Donmez, Boyle, & Lee, 2006; Horberry, Anderson, Regan, Triggs, & Brown, 2006; Jamson, Westerman, Hockey, & Carsten, 2004). Given the growing use of these systems, drivers may continue to adapt other strategies to accommodate their use of these in-vehicle tasks.

Driver safety systems designed to mitigate the effects of driver distraction may hold promise and has been shown to help enhance driver performance (Donmez, Boyle, & Lee, 2006). However, a driver's expectations of a system can chance with prolonged use. Trust and acceptance can change as drivers adapt to the system. Lee & See (2004) define trust as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability." Among attitudes towards technology, trust is an important factor that influences the use of and the reliance on automation (Lee & See, 2004). Therefore, trust can also influence the effectiveness of different feedback mechanisms that mitigate driver distraction.

Two useful dimensions of acceptance are perceived usefulness and satisfaction (Van Der Laan, Heino, & De Waard, 1997). Usefulness relates to the perceived system benefits such as effectiveness and assistance, whereas satisfaction assesses the desirability of the system. Acceptance may affect system use (Davis, Bagozzi, & Warshaw, 1989) and may be correlated with trust. For example, Davis et al. (1989) found that perceived usefulness of computers is highly correlated with self-reported current usage and self-predicted future usage. There is also research in e-commerce suggesting that perceived usefulness influences trust (Suh & Han, 2002). Donmez, Boyle, Lee & McGehee (2006) assessed how levels of automation affected acceptance of (perceived usefulness and satisfaction) and trust in distraction mitigation strategies. However, the relationship between acceptance and trust, and the change over prolonged system use was not explored.

The timing that feedback is provided to the driver can also influence their trust in the system. If the drivers cannot interpret the information from the system as expected, trust may diminish (Lees & Lee, 2007). With respect to driver distraction mitigation systems, feedback can be provided at different times in a drive. Donmez, Boyle, & Lee (2008) showed that differences in eye movements and driving performance over time were influenced by two types of feedback timing: feedback provided in real time and feedback provided after the drive is complete. The advantage of providing feedback in real time (i.e., concurrently with the driving task) is to help drivers with their immediate performance. Feedback that is provided immediately after the drive is over (i.e., retrospectively) will not impact their level of engagement while driving, but can have the benefit of calibrating driver's subjective performance by presenting a connection between intentions and events that occurred during a trip. Thus, a combination of both may be ideal to enhance immediate performance and help driver's learn safe driving habits (Donmez, Boyle, & Lee, in press).

In general, feedback on the level of distraction engagement can help alter driver behavior if trust in the system can increase over time. Even if the driver is not favoring the system initially, the long term use will depend on whether or not trust can be gained in the latter time period. If trust cannot be achieved over time, the driver will not accept the information and will ultimately not use the system as intended. Previous research has shown that trust evolves over time, increasing as users experience a reliable system, diminishing when they experience system failures, but gradually recovering after the system resumes reliable operation (Lee & Moray, 1992; Muir & Moray, 1996). It is therefore, important to understand how trust in distraction mitigation systems changes over time and what driver perceptions influence this change. This study examines how different timings of feedback influence driver's trust in feedback and how trust changes over time as related to driver's acceptance of feedback. The objective of this study is to observe whether trust increases over prolonged exposure. This was accomplished in a driving simulator study with two feedback mechanisms that were designed to mitigate the effects of driver distraction.

METHOD

Participants

There were 31 participants between the ages of 18 and 21 (female: n=15, $\overline{X}$ = 20.2, S = 0.56; male: n=16, $\overline{X}$ = 19.9, S = 0.93) in this study. All participants possessed a valid US driver's license, and had at least 2 years of driving experience. Participants were paid $15 per hour, and then had the opportunity to earn a bonus of up to $10.

Apparatus

The experiment was conducted with a medium-fidelity, fixed-based simulator with a 50-degree visual field powered by Global Sim, Inc.'s DriveSafety™ Research Simulator. All graphics for roadway layouts, markings, and signage conform to American Association of State Highway and Transportation Officials (AASHTO) and Manual of Uniform Traffic Control Devices (MUTCD) design standards. A 7-inch LCD (60-Hz frame rate at 640 x 480 resolution) mounted on the dashboard by a small stand was used in the experiment for the presentation of the visual messages used in the secondary task. The viewing angle from the driver's eye point is approximately 18 degrees. A Seeing Machines eye tracker was used to collect eye movement using the FaceLab 4.2™: an eye and head tracking system that enables analysis of natural behavior by using a set of cameras as a passive measuring device.

Experimental Design

The experiment was a mixed factorial design with feedback type as a between-subject variable: retrospective feedback (17 participants) and combined (concurrent and retrospective) feedback (14 participants). Each participant completed four experimental drives. Therefore, drive was a within subject variable. The independent variables examined in this study were age, gender, and feedback type.

The road geometry was identical for each drive. Participants followed a lead vehicle while performing a secondary task. The group in the retrospective feedback condition received information after each drive on their distraction level (as measured by an eye tracking system) and incidents that may have occurred during that drive. The group in the combined feedback condition received the same information in real-time in addition to receiving it after the trip. Further details about the study design can be found in Donmez, Boyle, & Lee (2008).

Response Variables

After each drive, trust in feedback was assessed using a five point Likert scale with values ranging from strongly disagree to neutral to strongly agree. For combined feedback, two separate questionnaires were administered; one for the concurrent feedback and one for the retrospective feedback.

A questionnaire was administered to assess acceptance measures (Van Der Laan et al., 1997) after each drive. The questionnaire consisted of nine questions that examined acceptance along two dimensions: usefulness and satisfying. Usefulness questions composed of rating the system on the following aspects: useful, good, effective, assisting, and raising alertness. Satisfaction dimension was rated on four other aspects of the system: pleasant, nice, likeable, and desirable. Before analysis, the acceptance questionnaire was recoded to fall along a scale of -2 to +2 (-2 representing the lowest level of acceptance and +2 the highest level). These numbers were then averaged to obtain a metric for usefulness and satisfying as defined in Van Der Laan et al. (1997). For the combined feedback condition, participants filled out two separate acceptance questionnaires for the concurrent and retrospective portion.

Proportional Odds Model

An ordered logit model, specifically proportional odds, was developed to predict the level of trust based on different feedback types to mitigate distraction, adjusted for individual differences (e.g., age and gender) and acceptance measures collected after each drive. Proportional odds model provides a strategy that takes into account the ordinal nature of the data (Stokes, Davis, & Koch, 2000) and is represented with a set of equations as:

$$
\begin{aligned}
&\ln\left[\frac{p_1}{1-p_1}\right] = \beta_{01} + \mathbf{\beta X}_i + \varepsilon \\
&\ln\left[\frac{p_1+p_2}{1-p_1-p_2}\right] = \beta_{02} + \mathbf{\beta X}_i + \varepsilon \\
&\vdots \\
&\ln\left[\frac{p_1+p_2+\ldots+p_n}{1-p_1-p_2-\ldots-p_n}\right] = \beta_{0n} + \mathbf{\beta X}_i + \varepsilon
\end{aligned}
\qquad (1)
$$

where p_1 represents the probability of strongly agree in system trustworthiness, p_2 was agree in system trustworthiness and so forth to p_5 being strongly disagree. None of the respondents indicated that they strongly disagree and therefore, the model was examined over 4 ordered responses. Thus, the "odds of trust" refers to multiple comparisons between the following possible levels of trust: "strongly agree" versus "agree", "neutral", and "disagree"; "strongly agree" and "agree" versus "neutral", and "disagree"; and "strongly agree", "agree", and "neutral" versus "disagree". The intercept for model n was represented by β_{0n}, and $\mathbf{\beta}$ is the matrix of coefficient estimates for each respective predictor variable, $\mathbf{X_i}$ (e.g., age, gender, acceptance), and ε is the error term associated with parameters not included in the model.

Repeated measures were accounted for by creating a population-average model. Because the data consists of repeated measures, generalized estimating equations (GEE) was used for estimation. GEE can handle continuous, categorical and time dependent explanatory variables. The model was fitted using PROC GENMOD in SAS 9.1, with the specifications of cumulative logit link function and multinomial distribution.

RESULTS

The majority of responses were "agree", or "strongly agree" (Figure 1). As stated earlier, there were no "strongly disagree" responses for any feedback timings, and "disagree" was observed only for concurrent feedback. Therefore, only four of the five levels of the ordinal response were modeled in the ordered logit model. Trust also appeared to increase with additional drives. Moreover, almost all drivers agreed or strongly agreed that they trust feedback if they perceived the system to be highly useful (Figure 2).

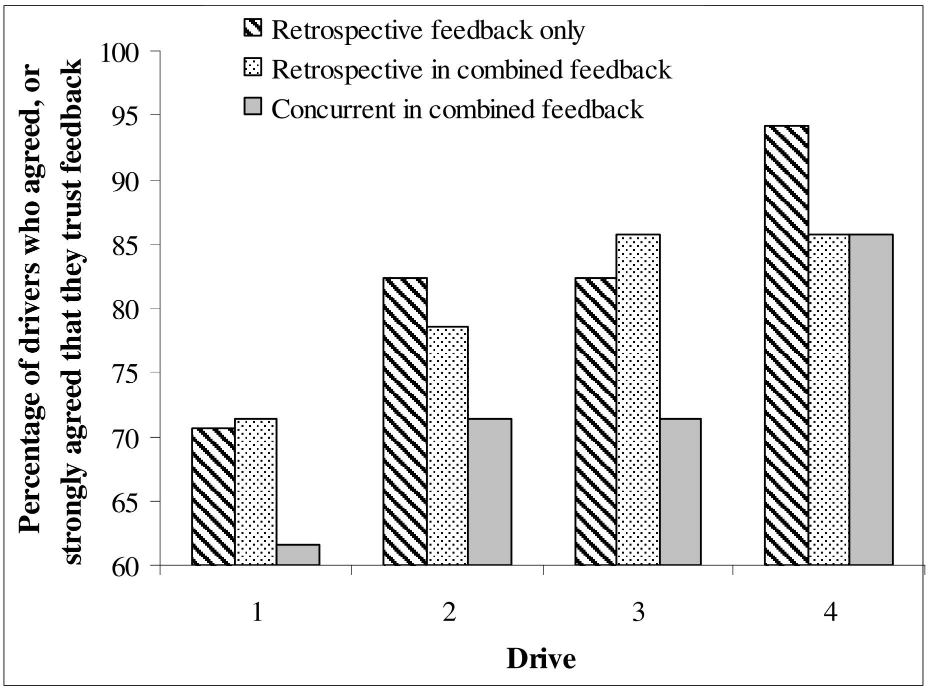

Figure 1. Percentage of drivers for each drive who agreed or strongly agreed that they trust feedback

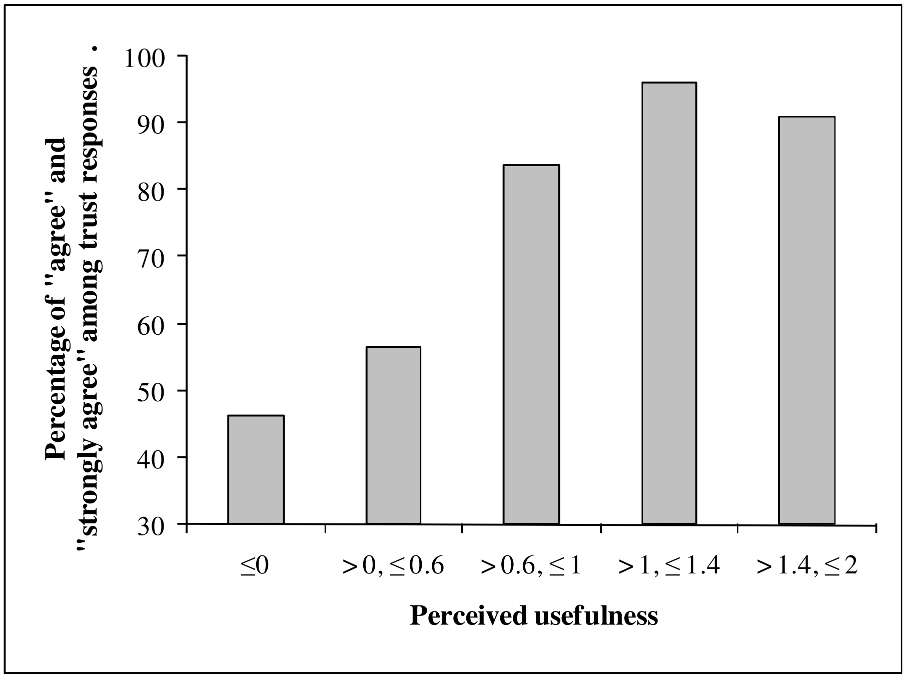

Figure 2. Associations between trust and perceived usefulness

Wald statistics for type GEE analysis revealed that usefulness score ($\chi^2(1)$=7.29, p=0.007), gender ($\chi^2(1)$=10.67, p=0.001), drive ($\chi^2(1)$=5.89, p=0.02), interaction of usefulness and drive ($\chi^2(1)$=4.13, p=0.04), and interaction of usefulness and gender ($\chi^2(1)$=5.90, p=0.02) were statistically significant. Type of feedback, age, satisfying score and associated interactions were not significant (p>0.05), and hence were not included in the final model (Table 1).

Table 1. Proportional odds model of increasing trust.

Parameter	Estimate	Standard Error	95% Confidence Interval (Lower, Upper)	Z	Pr > |Z|
Intercept1	-2.90	1.26	(-5.37, -0.44)	-2.31	0.021
Intercept2	1.14	1.10	(-1.02, *3.29)*	1.03	0.301
Intercept3	4.03	1.26	(1.56, 6.50)	3.20	0.001
Usefulness	1.03	0.88	(-0.69, 2.74)	1.18	0.239
Female	-3.78	1.16	(-6.05, -1.51)	-3.27	0.001
Drive	0.55	0.23	(0.11, 0.99)	2.43	0.015
Usefulness*Drive	-0.37	0.18	(-0.73, -0.01)	-2.03	0.042
Usefulness*Female	2.12	0.87	(0.41, 3.83)	2.43	0.015

Controlling for other covariates, drive effect on trust depended on perceived usefulness. Table 2 reports the estimated multiplicative increase in odds to trust feedback with an additional drive, for different usefulness levels; specifically at 95%, 75%, 50%, 25%, and 5% quartiles of usefulness: 2, 1.4, 1, 0.6, and 0, respectively. Additional drives increased the level of trust in the system, especially for neutral to moderate levels of perceived usefulness. For example, for moderate perceived usefulness (i.e., 1), one additional drive increased the odds of trusting feedback by 19%.

Table 2. Multiplicative increase in odds of trust with one additional drive at different perceived usefulness values.

Perceived Usefulness	**Estimate (Δ)**	$\chi^2(1)$	p	**95% Confidence Interval (CI)**
0 (i.e., neutral)	1.73	5.89	0.02	(1.11, 2.69)
0.6	1.38	6.22	0.01	(1.07, 1.78)
1 (i.e., moderate)	1.19	4.04	0.04	(1.004, 1.41)
1.4	1.03	0.08	0.78	(0.85, 1.24)
2 (highest possible usefulness response)	0.82	1.22	0.27	(0.58, 1.16)

Controlling for other covariates, gender effect on trust also depended on perceived usefulness. Table 3 suggests that for neutral to moderate levels of perceived usefulness in particular, males had higher likelihood of trusting the system than females.

Table3. Multiplicative increase in odds of trust for males vs. females at different perceived usefulness values.

Perceived Usefulness	**Estimate (Δ)**	$\chi^2(1)$	p	**95% Confidence Interval (CI)**
0 (i.e., neutral)	43.99	10.67	0.001	(4.54, 426.0)
0.6	12.33	9.87	0.002	(2.57, 59.06)
1 (i.e., moderate)	5.29	5.83	0.02	(1.37, 20.38)
1.4	2.26	1.20	0.3	(0.53, 9.73)
2 (highest possible usefulness response)	0.63	0.18	0.7	(0.08, 5.09)

DISCUSSION

The literature suggests that trust greatly influences system use (Lee & See, 2004). However, relatively few studies have investigated the factors that moderate changes in trust over prolonged system use. This issue has implications for the initial and lasting impact of crash countermeasures. The response to a driver safety system may be significantly different each time the driver uses the system. Studies that have examined driver performance measures have noticed this phenomena (Boyle & Mannering, 2004; Donmez et al., 2008). However, this outcome may be influenced by driver attitudes to these systems, such as trust, and acceptance.

The acceptance questionnaire used in the analysis composed of two dimensions: perceived usefulness and satisfaction (Van Der Laan et al., 1997). Usefulness dimension assessed system benefits such as effectiveness and assistance, whereas satisfaction assessed how likeable or desirable the system was. Among the two dimensions, perceived usefulness was associated with trust in the system.

The results of this study suggest that trust in distraction mitigation strategies can change over time; however this change is associated with the perceived usefulness of the system. Trust and perceived usefulness observed for the specific systems evaluated in this study were generally high. Therefore, the results have implications for moderate to high levels of trust. When perceived usefulness was very high, additional exposure to the system did not provide an increase in the trust level. This was a ceiling effect, where trust in the system was already high and could not get any higher. For neutral to moderate levels of perceived usefulness, trust increased with additional exposure to the system.

Differences in driving behavior between males and females have already been identified in other driving studies (Dejoy, 1992; Harre, Field, & Kirkwood, 1996; Lajunen & Summala, 1995). The current study shows that trust is another factor that is significantly associated with gender. The influence of gender on trust depended on perceived usefulness. For very high levels of perceived usefulness, gender did not have a significant impact on trust. However, for neutral to moderate levels of perceived usefulness, males trusted the system more than females. Research on personality suggests that females put more trust in their interpersonal relations (Feingold, 1994; Seiden & Bart, 1975) and typically place more trust in people. However, the findings of this study suggest that males are more favorable of these technological options in cars. This is also in line with previous research which suggests that women, in general, show more concern about the risks associated with technologies (Davidson & Freudenburg, 1996; Gardner et al., 1982; Pilisuk & Acredolo, 1988; Siegrist, 2000).

This study investigated the relationship between acceptance of a system and trust in the system. The acceptance responses collected on the two specific distraction mitigation systems changed from neutral to high levels. As one would expect, trust was also high in these distraction mitigation systems. Therefore, the relationship between perceived usefulness and trust identified in this study are only applicable to systems with high levels of acceptance and trust. There may be different time and gender effects on trust for systems that are generally perceived to be useless and annoying. Further research is needed to assess how trust is affected over time for systems that are not perceived to be useful. Moreover, this study investigated the associations between feedback timing, acceptance, and trust, but did not assess how trust guides behavior and attitudes. In order to have a better understanding of how trust influences system use, the role of trust as a mediating factor in guiding behavior should be studied.

CONCLUSIONS

Trust changes with prolonged use of a distraction mitigation system and is also associated with perceived usefulness of the system. The results also suggest that females put less trust in such systems than males which is consistent with studies that have been conducted in other domains where technological innovations have been considered. These findings provide insights into system use such that trust and acceptance should be examined along with driver performance measures. As change in driver behavior can occur with driver distraction, so can a change in behavior occur due to the system designed to mitigate the effects of distraction. These implications are important when designing these systems and need to be further considered and investigated.

ACKNOWLEDGMENTS

This research was conducted partially by the SAVE-IT program under contract by Delphi Corporation and sponsored by the U.S. DOT – National Highway Traffic Safety Administration – Office of Vehicle Safety Research and the National Science Foundation Career Award. Data collection for this project was provided, in part, by Mark Hoy and Gregory Scott.

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