How Humans Trust Autonomous Vehicles: A Study in Measurement Development and Personality Differences

David R. Garcia, Christine Kreutzer, and Karla A. Badillo-Urquiola

University of Central Florida, Psychology Department

Orlando, Florida

david.garcia@ucf.edu, christine_kreutzer@knights.ucf.edu, kbadillo@ist.ucf.edu

ABSTRACT

Recent advances in technology have improved the ability of vehicles to act autonomously, thereby enabling the implementation of these systems into the lives of the everyday consumers. For example, in the past three years several major vehicle manufacturers, suppliers, and technology companies have announced projects involving autonomous vehicles (AVs). While the notion of AVs has been popular within the military, the urgency to make them commonplace has gathered pace as companies outside the auto industry have illustrated the feasibility and benefits that AVs offer. However, in order to predict user adoption of these autonomous features, attitudes towards them must be understood. Thus, the purpose of the present work is to develop and validate a scale to quantify trust towards autonomous vehicles. The data was subjected to a factor analysis with Promax rotation, yielding two factors. A number of correlations between trust towards autonomous features and personality were also identified. Finally, differences in trust between autonomous levels were identified.

ABOUT THE AUTHORS

David R. Garcia graduated from the University of Central Florida (UCF) with a degree in psychology, and is currently a Master’s student in the Modeling and Simulation (M&S) program at UCF pursuing the Human Systems track. David’s research interests include user experience in wearable technology, human-autonomous vehicle interaction, human-robot interaction, and human-computer interaction. David hopes to pursue his PhD in a related field upon completing his Master’s.

Christine Kreutzer holds a Bachelor of Science in Psychology from UCF and is currently a doctoral student in the M&S program at UCF. She is also a graduate researcher at the Recent and Emerging Technology Research Organization. Her research interests include the use of technology and game-based therapies for mental health, military simulation training, serious game design, and user experience.

Karla A. Badillo-Urquiola is a Graduate Research Assistant at the Applied Cognition and Training in Immersive Virtual Environments Lab at the Institute for Simulation and Training. She graduated from UCF as a Ronald E. McNair Scholar with her Bachelor of Science degree in Psychology, a minor in Writing and Rhetoric, and a certificate in Interpretation and Translation. She is a recipient of the McNair Graduate Fellowship Program and pursuing her Master of Science in M&S at UCF. In March 2015, she was awarded the M&S Humanitarian Scholarship for the time and effort she puts into volunteering, and promoting M&S. Her research interests include: simulation-based training; immersive virtual training environments; physiological & human factors; behavior cue detection; terrorism and counter-terrorism. Her ultimate goal is to earn a position as a Science and Technology Research Scientist for the U.S. Intelligence Community.

How Humans Trust Autonomous Vehicles: A Study in Measurement Development and Personality Differences

David R. Garcia, Christine Kreutzer and Karla Badillo-Urquiola
University of Central Florida, Psychology Department,
Orlando, Florida
david.garcia@ucf.edu, christine_kreutzer@knights.ucf.edu, kbadillo@ist.ucf.edu

INTRODUCTION

Background

As vehicles with autonomous features become standard in today's market, so does the need to understand the intricate role human trust plays in the operation of these vehicles. Certainly, human trust towards autonomous vehicles (AVs) has become a salient issue in Human-Robot Interaction (HRI) literature. For example, when an autonomous car has anthropomorphized features, humans are more likely to trust the vehicle (Waytz, Heafner & Epley, 2014). However, previous research has indicated that humans are poor at monitoring automated systems (Hancock, Mouloua, Szalma & Oron-Gilad, 2007; Mouloua, Gilson & Hancock, 2003; Mouloua & Parasuraman, 1994; Parasuraman & Riley, 1997). Despite numerous advances in technology, autonomous systems still remain prone to automation failures (Wiener & Nagel, 1989; Mouloua & Koone, 1997). In addition to technical problems, there are a number of human factors design issues facing AV designers, such as displayed information, situation awareness, level of training and experience, control design, support from backup personnel or systems, data-link delays, and cognitive load limitations (Mouloua & Hancock, 2003).

Levels of Vehicle Automation

The National highway Traffic Safety Administration (2013) organizes vehicle autonomy as having five different levels.

- No-Automation (Level 0). In this level, there are no autonomous features in this vehicle. The driver is controlling all aspects of the vehicle at all times.
- Function-Specific Automation (Level 1). This level of autonomy includes vehicles with one or more specific control functions. Some examples of this are pre-charged brakes, or cruise control.
- Combined Function Automation (Level 2). Vehicles with combined function automation features have at least two principal functions that are designed to work together in order to relieve the operator of controlling those functions. Level 2 of vehicle automation is where a human begins to lessen their role as an operator and begins to take on the role of a supervisor.
- Limited Self-Driving Automation (Level 3). This level is defined as a vehicle that can enable the driver to relinquish complete control of functions critical to safety under some conditions. In this level, the driver must still be available for manual control of the vehicle.
- Full Self-Driving Automation (Level 4). This level implies that the vehicle is designed to monitor roadway conditions and perform functions critical to safety for the duration of a trip.

The Current Study

Despite the infiltration of autonomous features in the automotive market, and the potential design and safety issues associated with them, researchers have not yet explored attitudes towards these features. For example, how comfortable are humans with a car that can park itself versus a car that can pick you up, and take you to a destination? This research seeks to bridge this gap and put forth a validated measure to attempt to quantify these new constructs. More specifically, the purpose of this study is to explore the factor structure underlying a novel scale aimed at quantifying trust towards autonomous vehicles. It is hypothesized that scale ratings will converge to a single underlying dimension. It is also hypothesized that trust ratings will differ between each level of autonomy.

METHODOLOGY

Measure Development

Vignette Development. Vignettes reflecting the five levels of vehicle autonomy as identified by The National Highway Traffic Safety Administration were created. Each vignette describes the features of the corresponding level of autonomy.

Scale Item Development. Multiple databases were searched in order to identify meaningful articles using variations of the following terms: human-robot trust and HRI. Articles in which trust was the dependent variable were selected for review. Reference sections of these articles were then cross-referenced for additional support. Based on this exhaustive literature review, the most supported facets of robot trust were compiled. The authors reviewed and coded every article independently to record variables, study methodology, and research results. Subsequently, coders came together in a consensus meeting to extract similar and relevant variables.

Participants

A total of 211 participants from the University of Central Florida and the surrounding community were recruited for participation in this pilot study. A total of 57 participants were removed from the dataset due to low quality or incomplete responses, leaving a remainder of 154 cases in the final analysis.

Materials

Experimental Automation Trust Scale. Respondents rated the extent to which they agreed with a variety of vignettes depicting each autonomous level. These items were generated based on the facets of trust identified within the HRI literature (Schaefer, 2013; Joosse, Sardar & Evers, 2013; Parasuraman, Sheridan & Wickens, 2000; Yagoda & Gillan, 2012). Examples of items on this scale include: “I believe that this type of vehicle would be reliable,” “I believe that my interactions with this type of vehicle would be predictable,” and “I would trust this type of vehicle for my everyday travel.” Responses are rated on a 5-point Likert scale. A sub score is computed for each level of trust, as well as an overall trust score.

Big Five Personality Scale. A 50-item set of International Personality Item Pool (IPIP) Big Five Factor Markers (Goldberg et al., 2006) was administered. Responses were rated on a 5-point Likert scale. Several items were reverse coded. Scores for each of the five factors (i.e., openness, conscientiousness, extraversion, agreeableness, and emotional stability) were computed.

Technology Acceptance Questionnaire. An 11-item modified version of the Technology Acceptance Measure was administered. Respondents rated the extent to which they agreed with the items on a 7-point Likert type scale.

Experimental Design and Procedure

After reading and agreeing to the terms outlined in the informed consent, participants completed the surveys online through Qualtrics. The study utilized a within-subjects design. All participants completed each scale and corresponding vignette. The order in which participants received each vignette was randomized. The vignettes did not include the corresponding autonomous level.

RESULTS

Initial Analysis

A series of bivariate Pearson correlations were conducted to identify any relationships between trust and personality features. Relationships were found between trust towards function-specific automation and conscientiousness (r= .41, p= .02) and openness (r= .38, p= .04), and trust towards combined-function automation and openness (r= .40, p= .017). Additionally, trust towards limited self-driving automation and openness (r=. 47, p= .021) were related, agreeableness (r= .40, p= .032), and technology acceptance (r= .39, p= .028). Moreover, trust towards full self-driving automation was significantly related to openness (r= .47, p= .011), agreeableness (r= .48, p= .008), and technology acceptance (r= .47, p= .012). Finally, overall trust was related to openness (r= .57, p= .001) and technology acceptance (r= .39, p= .038).

A one-way repeated measures ANOVA was conducted to identify any differences in trust towards the autonomous levels ($F_{(4,150)}$= 9.98 , p=.000). Pairwise comparisons revealed significant differences in trust between every level.

Factor Analytics

Given the nature of the experimental measure, a series of five separate analyses were conducted for the scales corresponding to each level of trust.

Level 0: No Automation

A factor analysis using principal axis factoring was conducted on the 9 items with oblique (Promax) rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= .89. Bartlett's test of sphericity $\chi^2_{(36)}$ = 901.427, p=.000, indicated that correlations between items were sufficiently large. An initial analysis was run to obtain eigenvalues for each factor in the data. Two elements had eigenvalues over Kaiser's criterion of 1 and in combination explained 72.67% of the variance. Table 1 shows the factor loadings after rotation. The items that cluster on the same components suggest that Factor 1 represents trust towards the vehicle and Factor 2 represents trust in the operator.

Table 1. Level 0 Item Loadings

	Factors	
	1	2
I believe that this type of vehicle would be reliable	.826	-.238
I would trust this type of vehicle for my day-to-day travel.	.739	-.247
I believe that this type of vehicle would perform consistently.	.782	-.350
I believe that the vehicle would perform tasks in a timely manner.	.791	-.126
I believe that my interactions with this type of vehicle would be predictable.	.732	-.240
I believe that I could comprehend how to operate this type of vehicle.	.787	.141
I believe that I have the expertise to operate this type of vehicle.	.409	.684
I believe that I have the ability to influence the operation of this type of vehicle.	.262	.621
I believe that I could successfully operate this type of vehicle.	.479	.781

Table 2. Eigenvalues by Factor and Variance Accounted Level 0

	Eigenvalues		
Factors	**Total**	**% of Variance**	**Cumulative %**
1	5.084	60.222	60.222
2	1.121	12.455	72.676

Level 1: Function-Specific Automation

A factor analysis using principal axis factoring was conducted on the 9 items with oblique (Promax) rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= .90. Bartlett's test of sphericity $\chi^2_{(36)}$ = 881.987, p=.000, indicated that correlations between items were sufficiently large. An initial analysis was run to obtain eigenvalues for each component in the data. Two elements had eigenvalues over Kaiser's criterion of 1 and in combination explained 71.33% of the variance. Table 3 shows the factor loadings after rotation. The items that cluster on the same components suggest that Factor 1 represents trust towards the vehicle and Factor 2 represents trust in the operator.

Table 3. Level 1 Item Loadings

	Factors	
	1	**2**
I believe that this type of vehicle would perform consistently.	.668	-.429
I believe that this type of vehicle would be reliable.	.738	-.338
I would trust this type of vehicle for my day-to-day travel.	.312	.229
I believe that my interactions with this type of vehicle would be predictable.	.749	-.294
I believe that the vehicle would perform tasks in a timely manner.	.842	-.042
I believe that I have the ability to influence the operation of this type of vehicle.	.187	.792
I believe that I could successfully operate this type of vehicle.	.182	.816
I believe that I have the expertise to operate this type of vehicle.	.170	.814

Table 4. Eigenvalues by Factor and Variance Accounted Level 1

	Eigenvalues		
Factors	**Total**	**% of Variance**	**Cumulative %**
1	5.326	59.182	59.182
2	1.093	12.148	71.330

Level 2: Combined Function Automation

A factor analysis using principal axis factoring was conducted on the 9 items with oblique (Promax) rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= .86. Bartlett's test of sphericity $\chi^2_{(36)}$ = 674.002, p=.000, indicated that correlations between items were sufficiently large. An initial analysis was run to obtain eigenvalues for each component in the data. Two elements had eigenvalues over Kaiser's criterion of 1 and in combination explained 65.5% of the variance. Table 5 shows the factor loadings after rotation. The items that cluster on the same components suggest that Factor 1 represents trust towards the vehicle and Factor 2 represents trust in the operator.

Table 5. Level 2 Item Loadings

	Factors	
	1	**2**
I believe that this type of vehicle would perform consistently.	.758	-.271
I believe that this type of vehicle would be reliable.	.777	-.397
I believe that the vehicle would perform tasks in a timely manner.	.687	-.123
I would trust this type of vehicle for my day-to-day travel.	.390	.024
I believe that I could comprehend how to operate this type of vehicle.	.716	.222
I believe that my interactions with this type of vehicle would be predictable.	.668	-.299
I believe that I have the ability to influence the operation of this type of vehicle.	.272	.652
I believe that I have the expertise to operate this type of vehicle.	.219	.732
I believe that I could successfully operate this type of vehicle.	.370	.789

Table 6. Eigenvalues by Factor and Variance Accounted Level 2

	Eigenvalues		
Factors	**Total**	**% of Variance**	**Cumulative %**
1	4.578	50.861	50.861
2	1.317	14.637	65.498

Level 3: Limited Self-Driving Automation

A factor analysis using principal axis factoring was conducted on the 9 items with promax rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= .89. Bartlett's test of sphericity $\chi^2_{(36)}$ = 708.510, p=.000, indicated that correlations between items were sufficiently large. An initial analysis was run to obtain eigenvalues for each component in the data. Two elements had eigenvalues over Kaiser's criterion of 1 and in combination explained 65.98% of the variance. Table 7 shows the factor loadings after rotation. The items that cluster on the same components suggest that Factor 1 represents trust towards the vehicle and Factor 2 represents trust in the operator.

Table 7. Level 3 Item Loadings

	Factors	
	1	**2**
I believe that this type of vehicle would be reliable.	.753	.473
I believe that this type of vehicle would perform consistently.	.835	.479
I would trust this type of vehicle for my day-to-day travel.	.252	.085
I believe that my interactions with this type of vehicle would be predictable.	.732	.595
I believe that the vehicle would perform tasks in a timely manner.	.731	.589
I believe that I could comprehend how to operate this type of vehicle.	.848	.677
I believe that I have the expertise to operate this type of vehicle.	.677	.268
I believe that I have the ability to influence the operation of this type of vehicle.	.379	.651
I believe that I could successfully operate this type of vehicle.	.377	.848

Table 8. Eigenvalues by Factor and Variance Accounted Level 3

	Eigenvalues		
Factors	**Total**	**% of Variance**	**Cumulative %**
1	4.827	53.632	53.632
2	1.112	12.353	65.985

Level 4: Full Self-Driving Automation

A factor analysis using principal axis factoring was conducted on the 9 items with promax rotation. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO= .86. Bartlett's test of sphericity $\chi^2_{(36)} = 776.975$, p=.000, indicated that correlations between items were sufficiently large. An initial analysis was run to obtain eigenvalues for each component in the data. Two elements had eigenvalues over Kaiser's criterion of 1 and in combination explained 66.35% of the variance. Table 9 shows the factor loadings after rotation. The items that cluster on the same components suggest that Factor 1 represents trust towards the vehicle and Factor 2 represents trust in the operator.

Table 9. Level 4 Item Loadings

	Factors	
	1	**2**
I believe that this type of vehicle would be reliable.	.821	-.282
I believe that my interactions with this type of vehicle would be predictable.	.791	-.269
I believe that this type of vehicle would perform consistently.	.798	-.338
I believe that I could successfully operate this type of vehicle.	.774	.431
I believe that the vehicle would perform tasks in a timely manner.	.744	-.130
I would trust this type of vehicle for my day-to-day travel.	.080	-.052
I believe that I could comprehend how to operate this type of vehicle.	.254	.762
I believe that I have the expertise to operate this type of vehicle.	.259	.781
I believe that I have the ability to influence the operation of this type of vehicle.	.186	.458

Table 10. Eigenvalues by Factor and Variance Accounted Level 4

	Eigenvalues		
Factors	**Total**	**% of Variance**	**Cumulative %**
1	4.823	53.592	53.592
2	1.148	12.759	66.351

DISCUSSION

The aim of the present pilot study was to examine the factor structure of an experimental metric designed to quantify attitudes towards different levels of autonomy in vehicles. In particular, factors underlying trust towards autonomy were identified. The analyses consistently revealed two underlying components of trust towards autonomous vehicles. In examining the items that loaded on each of these two factors, themes become apparent based upon the content of the items rated. We therefore offer initial labels for each factor, which we believe is representative of the overall theme of the items. Based on the nature of the items that consistently loaded on Factor 1 across all levels, it appears as though the instrument measures trust towards the autonomous vehicle features. Moreover, given the nature of the items which consistently loaded on Factor 2 at each level, it appears as though the instrument also measures the operator's trust in his or her own ability to successfully operate the vehicle. This factor may be tapping at self-efficacy, which is defined as personal judgments of one's capabilities to organize and execute courses of action to attain designated goals (Bandura, 1977). Given that self-efficacy is domain or task-specific (Bandura, 1997), this second factor may be representative of self-efficacy in the domain of automated vehicle operation.

Correlating the factors with personality also showed that trust towards autonomy may be expressed differently by individuals with different personality features. In particular, openness was related to trust towards all autonomous levels, as well as overall trust. This is not surprising, given that individuals high on this trait typically have a curiosity and appreciation for novel creations or experiences. In addition to openness, trust towards level 1 was related to conscientiousness. It is likely that conscientiousness is related to trust of this lower autonomous level as individuals high on this trait prefer familiarity (Costa & MacCrae, 1992), and it is likely that autonomous features representative of level 1 is what the average consumer is currently most familiar with. Additionally, conscientious individuals tend to aim for achievement (Costa & MacCrae, 1992), so it may be that these individuals feel more capable of successfully operating a vehicle of this level of autonomy as opposed to one with greater autonomy. Moreover, trust towards levels 3 and 4, as well as overall trust, was related to agreeableness and technology acceptance. Individuals high on agreeableness and technology acceptance tend to be more trusting and optimistic (Rothmann & Coetzer, 2003), so it appears that these attitudes generalize to autonomous vehicles as well. In addition, this study identified a significant difference in trust at each level of autonomy. More specifically, there was an attenuation of trust at each level of autonomy, suggesting that in general, individuals are more trusting of vehicles exhibiting fewer autonomous features. Thus, future research should examine factors that may increase the uptake of more advanced autonomous features.

The technological capacities of vehicles have vastly increased in recent years, leading to the advancement of both the functional capability and autonomy of current systems. With these advancements, autonomous features have become increasingly prevalent within everyday vehicles. This has led to a transition of the human role from an operator to that of a supervising member, assistant, or even bystander. As such, the intricacies of interaction have changed to where consumers must place increasing amounts of trust into these technological features. Thereby, the individual's trust in that system takes a prominent role in the success of any interaction and therefore the future use of the vehicle.

Despite the infiltration of autonomous vehicles faced by consumers, researchers have not examined attitudes towards various autonomous features. This is problematic, as vehicle manufacturers and government agencies responsible for vehicle regulations must understand if consumers are receptive of these recent and ongoing advancements. The deployment of AVs today is less about technological capabilities and more about the ability of stakeholders to implement such vehicles into an everyday environment. One barrier to successful deployment may be a lack of consumer trust. Thus, this study makes the contribution of providing a means to quantify trust towards autonomous features in vehicles. Additionally, this study identified how different types of consumers feel about a variety of autonomous features that are gaining popularity. Thus, the results of this study have implications for vehicle manufacturers, as better understanding their consumers will help them to design more desirable vehicles, thereby increasing profit and user adoption.

The validation of this measure will also provide fruitful avenues for future research. According to Schaefer (Schaefer, 2013) individuals' mental models change as trust changes from pre- to post-interaction with a robot. Future work should examine if a similar relationship exists within the context of autonomous vehicles. That is, future research should examine how operating vehicles of varying autonomy changes individuals' degree of trust and thereby, mental models. Moreover, this measure could be utilized to quantify these changes in trust from pre- to post-interaction. An additional avenue for future work is related to trust as it applies to expansion and transition of the human role. The human element is often overlooked or even forgotten during the design and development process (Schaefer, 2013). Thus, future work should be conducted to further understand the differences in trust perceptions between individuals as it applies to this process.

REFERENCES

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review*, 84, 191–215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Goldberg, L. R., Johnson, J. A., Eber, H. W., Hogan, R., Ashton, M. C., Cloninger, C. R., & Gough, H. C. (2006). The International Personality Item Pool and the future of public-domain personality measures. *Journal of Research in Personality, 40*, 84-96.

Hancock, P., Mouloua, M., Gilson, R., Szalma, J., & Oron-Gilad, T. (2007). Provocation: Is the UAV control ratio the right question? *Ergonomics in Design*, *15*(1), 7.

Joosse, M., Sardar, A., Lohse, M., & Evers, V. (2013). Behave-ii: the revised set of measures to assess users' attitudinal and behavioral responses to a social robot. *International journal of social robotics*, *5*(3), 379-388.

Mouloua, M., & Koone, J. (1997). *Human-Automation Interaction: Research and Practice.* Hillsdale, NJ: Erlbaum.

Mouloua, M., & Parasuraman, R. (1994). *Human performance in automated systems: Recent research and trends*. Hillsdale, NJ: Erlbaum.

Mouloua, M., Gilson, R., & Hancock, P. (2003). Human-centered design of unmanned aerial vehicles. *Ergonomics in Design: The Quarterly of Human Factors Applications*, *11*(1), 6-11.

National Highway Traffic Safety Administration. (2013). Preliminary statement of policy concerning automated vehicles. *Washington, DC*.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 320-253.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, *30*(3), 286-297.

Rothmann, S., & Coetzer, E. P. (2003). The big five personality dimensions and job performance. *SA Journal of Industrial Psychology*, *29*(1), p-68.

Schaefer, K. E. (2013). *The Perception and Measurement of Human-robot Trust* (Doctoral dissertation, University of Central Florida Orlando, Florida).

Waytz, A., Heafner, J., & Epley, N. (2014). The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle. *Journal of Experimental Social Psychology*, *52*, 113-117.

Wiener, E. L., & Nagel, D. C. (Eds.). (1989). *Human factors in aviation*. Gulf Professional Publishing.

Yagoda, R. E., & Gillan, D. J. (2012). You want me to trust a ROBOT? The development of a human–robot interaction trust scale. *International Journal of Social Robotics*, *4*(3), 235-248.