Let Tesla Park Your Tesla: Driver Trust in a Semi-Automated Car

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Abstract – **The reality of highly automated vehicles on every road seems increasingly possible. With companies such as Tesla, Google, Toyota, and many others racing to provide a fully autonomous vehicle, the need for research on self-driving cars has never been greater. Until recently, however, most of this research had been conducted in a sterile lab environment devoid of any real consequences. For that reason, we join a host of other researchers in evaluating human-automation interaction in the real world associated with miscalibrated trust. As previous research has shown, drivers can either over- or under trust a vehicle's automated features. To evaluate this in these in a realistic setting, we had participants use the Autopark feature in a Tesla Model X or park the car themselves in both parallel and perpendicular scenarios. Parking times, driver trust, self-confidence in their own ability to park, and workload were all evaluated throughout the experiment. Preliminary analyses into the data are reported. Trends for the interactions between parking condition (self versus auto) and the parking type (parallel versus perpendicular) emerged for both trust/self-confidence and workload. Data collection is still ongoing to evaluate whether these trends hold, and if they emerge as significant. In all, this study contributes to the growing body of literature which seeks to understand the complexities of human-automation interaction in the real world.**

Index Terms – Self-parking, Tesla, Trust in automation

INTRODUCTION

An increase in popularity of partially automated vehicles has taken place as more vehicles with these level 2 features are available [1]. There has also been a concurrent increase in research on these self-driving capabilities [2]–[5]. These studies have examined various aspects of human-automation interaction (HAI). This includes everything from transfer of control back to the human driver [4], [6], to preferences for automation's driving styles [7]. However, it has not been until recently that these evaluations of HAI in vehicles has escaped the sterile lab environment and moved into the real world [5], [8], [9].

The findings from these early, real-world studies indicate complacency and over-trust which can result in worse situational awareness (SA) [5], [9]. Studies have shown a propensity to over-trust robots in emergency scenarios [10], and over-reliance on automated systems which have demonstrated a lack of reliability [11]. There have been efforts towards the development of an 'adaptive trust calibration' system which would hopefully combat over-trust and over-reliance[12]. Such a system would cue an individual to 'notice what has been happening in the environment.' [12] We believe this to be a promising option for cars in the future, however, this type of system has yet to be developed. While results have indicated correlations between performance between regaining control in both the real world and simulator [4], it is imperative that we evaluate the litany of simulator based results in the real world, especially given that risk has been shown to play a significant role in situational trust [13].

Automated features that have been evaluated include (list features). Despite the wide availability of parking assist systems in major car brands, few researchers have evaluated the potential benefits of these systems. To our knowledge, only one other published study has evaluated human interactions with self-parking features [2]. To do this, authors examined self-reported level of stress as well as the heartrate of participants. With repeated exposures both stress and heartrate decreased. While this stress level *could* be indicative of changing levels of trust over time, trust was not explicitly measured. Additionally, it is hard to establish that lower levels of arousal indicate greater levels of trust, as excitement with the experience could have similarly affected arousal [14]. In addition to not being asked about trust, there were no behavioral measures, such as interventions, that could have indicated levels of trust [15].

A key difference in our study, compared to the majority of studies already completed on trust in partially automated vehicles, is that our study takes place in a real world. We believe we are the first to evaluate trust in a parking system, and among the first to evaluate trust in a real world automated driving task e.g. [2], [4], [5], [9].

In the present study we evaluated trust/distrust in, and workload with, the Autopark feature found in the Tesla Model X. Participant interventions, were recorded as well. We compared self-parking versus the Tesla's Autopark feature because we wanted to evaluate any core benefit conferred by the use of the Autopark. Any observed benefit would be in line with research which has already indicated a benefit for using a parking assist feature [16]. Additionally,

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we compared parallel versus perpendicular parking because of the inherent difference in difficulty. These preliminary results are contextualized in the discussion. We anticipated that there would be a workload benefit for using the Autopark (when compared to self-park) during parallel parking trials, but not in the perpendicular trials. We also anticipated that there would be a context specific trust effect between Autopark use in the perpendicular versus parallel trials.

METHOD

I. Participants

Seven participants completed a series of parking trials with a Tesla Model X (Figure 1). Participants were all undergraduate students and were recruited from the available pool of students at the U.S. Air Force Academy.

Figure 1. The Tesla Model X used for research at the U.S. Air Force Academy.

II. Stimuli & Apparatus

Our experiment was setup with two separate parking setups: perpendicular and parallel. When the participant was perpendicular parking, two cars were set up on either side of the Tesla's parking spot so that the Tesla had a designated parking spot. Although the parking spots were marked diagonally in the parking lot, the Tesla was incapable of parking itself in a diagonal spot, thus the parking was set up to have the Tesla park perpendicular to the curb between the two cars. When the participant was parallel parking, two cars were set up in front of and behind the Tesla's parking spot so that the Tesla had another designated parking spot. In both setups, the experimenter's cars were far enough away from each other for the Tesla to effectively autopark itself.

For the perpendicular parking setup, the Autopark occurred in three distinct stages (Figure 2). In the first stage the car began to back up towards the parking spot before stopping. In the second stage the Tesla pulled forward to square itself with the parking spot. In the final stage, the Tesla backed up completely into the parking spot and completed the parking trial. On rare occasions, the Tesla pulled forward and backed up again if it was not able to square itself during the second stage.

Figure 2. The three distinct stages of the Tesla's Autopark during perpendicular trials.

For parallel parking, the Tesla's Autopark feature involved very similar stages to its perpendicular parking (Figure 3). In the first stage, the car began to back in to the parallel spot before stopping. In the second stage, the Tesla pulled forward in the parallel spot to square itself. In the final stage, the Tesla backed up again to even itself in-between the experimenter's cars. Similar to the perpendicular autoparking, the Tesla could have pulled forward and backed in several times if it was not square during the second stage.

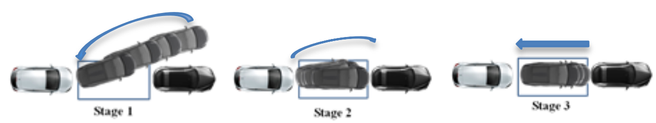

Figure 3. The three distinct stages of the Tesla's Autopark during parallel trials.

For this study we collected the behavioral information about total number of trials (a trial consisted of the participant driving past the parking spot in an effort to engage the Autopark, regardless of whether it was successful), and the number of trials in which participants intervened (by either hitting the brake or turning the steering wheel).

After every block of trials (employing the Autopark feature and self-parking), participants were also asked to indicate their level of trust in either the Autopark or their own abilities (dependent on which trial they were in). They were also given the NASA TLX between every block of trials. A post-experimental survey was also administered to participants involving both open-ended questions and scales (Table 1).

Table 1

Summary of Measures

Measure	What is being measured
NASA TLX	Workload
Interventions	Vehicle Performance & Drivers' Trust
Post-Experimental Questionnaire	
Scales	Trust, Self-Confidence, Use Preferences
Open-ended	First impressions, Development of Trust, Experience, Autopark's Performance

III. Procedure

After providing informed consent, participants were asked to show a valid driver's license. Participants were then instructed to get into the passenger seat and buckle the seatbelt while the experimenter drove them to the experimental location. The experimenter and the participant switched seats and the participant was told to park the car themselves (self-parking trials). For perpendicular parking, the participant drove around the next row to circle back around to the spot. For parallel parking, the participant drove around two rows to circle back to the spot.

After the four self-parking trials, the participants were then told how to engage the Tesla's Autopark feature and was instructed to circle around and use it. If the participant was unsuccessful in their attempts to engage the auto-parking, they were instructed to go around and try again. Participants completed four self-parking trials and four Autopark trials in both setups (perpendicular vs parallel). Whether participants started with parallel or perpendicular parking was randomized. However, for each set up they always completed four self-parking trials before completing four Autopark trials. Between every trial, trust and workload were evaluated.

After the trials were completed, the experimenter drove back to the parking garage, the participant completed the post-experimental questionnaire, were debriefed, and sent on their way. Each experimental session lasted 45 minutes.

Results

Because data collection is still ongoing, in lieu of running statistical tests we have opted for providing descriptive statistics. This was to avoid issues associated with 'p-hacking'[17].

The driver intervened (by stopping the vehicle) on 19.6% of the trials. However, of all the interventions only 18.2% occurred on parallel parking trials, with the remaining 81.8% of interventions occurring during the perpendicular trials.

Participant self-reported trust in the Autopark and self-confidence in their own ability to park for both the parallel and perpendicular conditions are reported in Table 2 and graphed in Figure 4.

Table 2

Trust and self-confidence

Condition	*M* (*SD*)
Parallel	
Trust in Autopark	15.29 (6.87)
Self-confidence	12.07 (6.21)
Perpendicular	
Trust in Autopark	13.93 (5.27)
Self-confidence	16.14 (3.44)

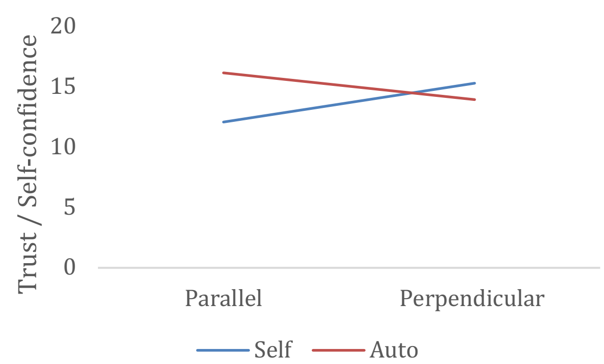

Figure 4. Trust and self-confidence scores for the self parking trials (blue) and the Autopark trials (red), by parallel and perpendicular parking conditions.

Participants indicated similar levels of trust in the automation overall ($M = 13.64$, $SD = 7.77$), as they did of self-confidence in their own abilities to park ($M = 13.36$, $SD = 6.25$).

Self-reported workload is plotted in Figure 5.

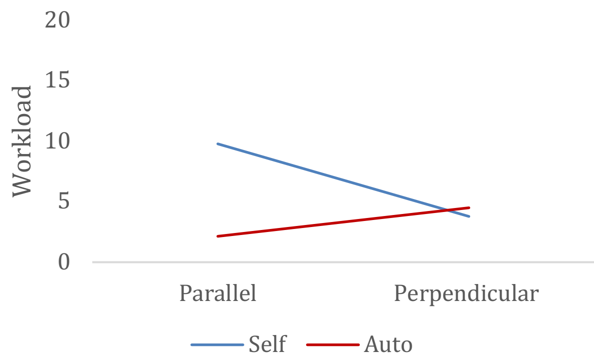

Figure 5. Workload for the self-parking trials (blue) and the Autopark trials (red), by parallel and perpendicular parking conditions. Workload was assessed by the NASA TLX.

Of the seven subjects, four indicated that they would prefer to use the Autopark feature, with the remaining three preferring to park the vehicle themselves. From the open-ended questions, several trends in the data emerged. First, participants indicated that they first began to trust the Autopark feature after it was able to successfully park (e.g. “After the first time it parked itself perfectly.”) Two other themes began to emerge when participants were asked about their first impressions with the Autopark feature. Several of the participants indicated a degree of skepticism (e.g. “Hesitant to let something I couldn’t see control this very expensive car.”) The second theme was the degree of amazement with the feature (e.g. “very impressive”).

Discussion

The goal of this study was to investigate the use and trust of a Tesla Model X’s Autopark feature. To do this, we had participants complete trials with both the Autopark and with parking the car themselves, for both perpendicular and parallel parking spots. Because this was a preliminary investigation, and because of the small sample size, we only evaluated the data with descriptive statistics and qualitative analyses.

While this research represents only a preliminary evaluation of the technology, we believe this study to be unique for several reasons. First, typical driving studies are focused on adaptive cruise control and highly autonomous driving, but not autonomous parking. To our knowledge, this is only the second study that has investigated autonomous parking[2]. Additionally, for this study we were able to compare and contrast the trust and workload associated with both parallel and perpendicular parking for when the participant parks themselves versus when they employ the Autopark. This comparison is an important one to make as we start to understand the nuances of situational trust in the real world [13].

One of the trends that emerged from the data was the difference in rates of intervention between the parallel and perpendicular trials during which the Autopark was engaged. We believe this is likely because of the Autopark backing into spaces, which is a relatively rare occurrence here in the United States. Whereas backing into the space is typical for parallel parking (and even required if you are to believe George Costanza from Seinfeld!), the novelty of backing towards the spot for perpendicular parking may have led to less trust from the participants.

Another trend that emerged from the data was the crossover interaction in self-reported trust/self-confidence. Whereas participants indicated lower levels of self-confidence when parallel parking than they did when perpendicular parking, the opposite trend emerged for their trust in the Autopark. While it is entirely speculative at this point, it is conceivable that trust in the Autopark is contingent upon the belief that it is more capable at parking in a given situation, than is the participant.

While the self-reported workload did not appear to be high for participants at any point in the study, the data suggest that using the Autopark resulted in a workload as low or lower (in the case of parallel parking) as experienced when the participant had to park themselves. This is consistent with an abundance of other literature which suggests use of automation decreases workload, e.g. [9], [18], [19].

Finally, we have been able to add to the growing body of literature using real automated vehicles [2], [5], [8], [9], [20]–[24]. Adding a degree of risk and vulnerability for the participant is a critical condition that is not usually added in traditional lab experiments. Due to the real-world consequences of this study, we believe that our results are more ecologically valid and representative of actual behaviors with autonomy in the real world.

It is also critical to note that none of the participants in this study had any experience using the Autopark feature before. Evaluation of this type with novices is critical given the significant distrust that novices have of parking assist features. A survey suggested that 72% of American drivers would not trust a parking assistance feature to park the car [16]. While trust in these partially-automated vehicles should be evaluated with regular users, it is imperative to study the early interactions of novices, with such technology.

There were several limitations to this study that should be highlighted to improve further studies with Autopark-like features. For both conditions, the parking spots we used may not be representative of all of the possible parking situations. The perpendicular spot was on a hill and slanted which could have adversely affected driver interventions. Additionally, the parallel spot was on the driver’s side which is only really used on one-way streets.

The experiment could have also suffered from social facilitation effects. Throughout the whole experiment, an experimenter sat in the passenger seat next to the driver. It is possible that this affected driver intervention behaviors in ways unbeknownst to us. Future studies should seek to examine the ways in which driver intervention behavior changes as a function of having the experimenter in and out of the vehicle.

CONCLUSION

This research compared participant reactions when self-parking versus using the Tesla's Autopark. We did this for both parallel and perpendicular parking spots. While this research constitutes only a preliminary exploration into the data, trends seem to be emerging. Among the trends were interactions between the parking condition (self versus auto) and the parking type (parallel versus perpendicular). While only descriptive statistics were reported, this research is still ongoing.

This research contributes to the field by evaluating trust and driver behaviors in the real-world, by using a partially-automated parking feature in the Tesla Model X.

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ACKNOWLEDGMENT

This work was supported by Airforce Office of Scientific Research Grant 16RT0881. The views expressed in this paper are those of the authors and do not reflect those of the U.S. Air Force, Department of Defense, or U.S. Government.

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