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Examining Driver Takeover Decisions and Trust of AVs at Rural Intersections

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DISCLAIMER

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16. Abstract
The goal of this work was to explore whether the complexity of different rural intersections influenced driver trust and comfort in a conditionally automated vehicle (i.e., Level 3 SAE) navigating the intersection for them. In an online survey platform (UMN Qualtrics), 271 participants watched five brief curated videos of a simulated automated vehicle navigating different rural intersections, with or without the presence of traffic. Participants were asked to make a decision about whether they would like to take over manual control of the vehicle and then rated their trust and comfort with the automated vehicle (AV) navigating each intersection. Intersection type was not found to be predictive of AV trust and comfort with navigating the different intersections, however, drivers' takeover decisions, level of education, past experience driving on J-turn intersections, and residence location predicted the level of trust and comfort with the automated vehicle. Additionally, predictors of being more comfortable with Level 3 automated vehicles driving on J-turn intersections included education, having more automation features (e.g., adaptive cruise control, lane keeping assist) in their existing vehicles, and the belief that J-turns are a good idea. The outcome of this work led to the development of a repository of curated simulated videos that were made publicly available for future research projects.

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Level 3 driving automation, simulation, rural areas, takeover decision making, trust, comfort, human factors	No restrictions.

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1. Introduction

Rural thru-STOP intersections consistently experience high rates of serious injury and fatal crashes (Preston et al., 2004). The dynamics of high speed on major roads and crossing vehicles from minor roads at these intersections create ample opportunity for severe, often deadly, angled collisions (Preston et al., 2003). A novel infrastructure approach to mitigate unsafe driver exposure is the J-turn intersection, sometimes called the restricted crossing U-turn intersection (RCUT), reduced conflict intersections (RCIs), or superstreet intersections. These unconventional intersection designs target yield- or stop-controlled intersections or signalized intersections on four-lane, divided highways (Bared, 2009).

Although J-turns can increase travel time by approximately one minute compared to conventional intersections, previous research suggests that J-turns greatly reduce overall crash rates and the number of injury-related and fatal crashes (Al-Omari et al., 2020; Inman and Haas, 2012; Edara, 2005; Sun et al., 2019; Moreland et al., 2024).

While J-turns have demonstrated effectiveness in reducing fatal crashes, they have not been met with uniformly positive support from public stakeholders (Inman and Haas, 2012; Al-Omari et al., 2020; Sun et al., 2019; Adsit et al., 2021; Edara et al., 2013). Road users may be resistant to J-turn implementations due to the required non-conventional movements to navigate the intersection, as well as perceptions about increases in travel time, potential physical constraints on farm vehicles and commercial trucks, and constrained access to businesses (Adsit et al., 2021; Ott et al., 2012). Further, there may be a tradeoff of reduced catastrophic errors at these intersections (e.g., angle crashes due to crossing through an unsafe gap) with increased minor errors (e.g., sideswipe crashes due to late merging/lane change) due to confusion or uncertainty by drivers unfamiliar with J-turns, given that property damage only crashes show less evidence of improvement (Ulak et al., 2020) while serious crashes are dramatically decreased. J-turns are beneficial for reducing dangerous crashes at intersections, but the novelty of their navigation, along with the stagnant minor crash rates, may risk rejection by some public stakeholders.

Combining the J-turn intersection with advanced driver assistance systems (ADAS) technologies may introduce new challenges with drivers manually taking over ADAS at J-turns. The safety advancements of future automated vehicles are expected to further reduce serious injury and fatal crashes at high-risk intersections. However, their proliferation in our fleet is dependent on public trust. Past research has demonstrated that drivers may lose trust in automated vehicles when select use cases, such as drowsy driving, are considered (Morris et al., 2023). A pilot study by Morris and colleagues (2021) expanded on this work and found comfort with automated vehicles navigating complex or novel environments, such as J-turns, varied based on the perceived capabilities of the automation. Specifically, drivers felt most comfortable with highly automated vehicles, i.e., Level 4 and Level 5 automation, navigating vehicles but less comfortable with lower levels of automation. However, another study found women to be less trusting of imagined Level 5 vehicles than men, suggesting that trust in highly automated vehicles is not uniform across drivers (Schwieters et al., 2021). Such findings suggest drivers of emerging vehicles with levels of automation capable of self-navigation through J-turns (e.g. level 3) or other atypical designs may be prone to manual take-overs at the intersection, risking a potential loss of safety that the automation could provide in decisions such as safe gap selection.

Further, current and future vehicles equipped with ADAS technologies may have difficulty in navigating J-turns or other complex intersection designs and will instead transfer manual control of the vehicles to drivers. Vehicle automation is predicted to fail when it is outside of the Operational Design Domain (ODD), such as known external conditions of infrastructure irregularities, such as work zones and highway exits (Chen et al., 2023). This possibly at J-turns demonstrates a common issue with automation in that automation often fails when the task is most complex and hardest for humans to manage. Given documented navigational errors of naïve drivers to J-turn intersections who have been in full manual control leading up to the intersection (Morris et al., 2023), drivers' navigational errors of the novel intersection may be exaggerated due to out-of-the-loop (OOTL) syndrome prior to hand-off of control to the human driver. Identifying the potential shifts in driver errors at J-turn intersections following ADAS-supported driving and identifying potential solutions to improve performance and driver trust is critical to advance the development of automated vehicles for rural driving environments. There is a need to effectively communicate to drivers when automation is reaching the limit of its ODD to prepare drivers for upcoming, and likely challenging, take-over conditions (Carsten & Martens, 2019).

Background

Past work suggests that driving performance under different driving conditions and roadway environments can vary when receiving a takeover request (TOR) from an automated vehicle equipped with lower levels of automation. For example, when asked to engage in a lane-keeping task, driver TOR time was shorter when driving in simulated urban areas compared to driving on simulated highways while response times were found to be similar when completing a lane-changing task (Du et al., 2024). Other studies suggest that takeover performance is influenced by driving style. One study comparing active driving (i.e., hands-on, feet-on) to passive driving (i.e. hands-off, feet-off) using ADAS technologies found that passive driving resulted in more variable deceleration rates compared to those in active driving groups (Yamani et al., 2024).

Additionally, a number of studies have evaluated the role of driver trust and comfort using ADAS technologies. Trust in automated driving systems increases after experience (Du et al., 2024; Manchon et al., 2023). However, the initial level of driver trust in the system may influence further trust calibration and modulate the effect of automation performance (Manchon et al., 2023). Experience with automation may also influence the degree of comfort using ADAS systems. One study examining the driving experiences of inexperienced motorists using SAE Level 2 automation over time found that the reported stressfulness of automated driving decreased over time and drivers reported feeling increasingly comfortable driving with automation without monitoring the system too closely (Sanbonmatsu et al., 2024). Similarly, a real-world study with automated vehicles found that drivers reported an increase in technology acceptance, trust, and perceived safety after experiencing partial automation on a public highway (Wilson et al., 2020). However, other studies show no change before and after the use of ADAS technologies (Yamani et al., 2024) and that driver perception of trust in AVs can decrease after a driving experience, especially if the driver intervenes (De Cet et al., 2023).

The presence and design of an in-vehicle human-machine interface (HMI) may influence driver performance and trust using ADAS technologies. Kim and colleagues (2024) examined various in-vehicle user interfaces that provided drivers with information about performing different driving maneuvers when navigating various highway scenarios (e.g., overtaking, passing a roundabout) and found that providing drivers with information related to the maneuvers of driving enhanced driver trust and acceptance without increasing driver workload. Further, providing driver maneuver information through auditory alerts resulted in greater trust and acceptance compared to when the information was provided visually (Kim et al., 2024). Other work suggests that using additional semantic information can shorten takeover reaction time, improve takeover quality, maintain a balanced driver workload and increase driver subjective acceptance and trust in the automated system (Liu et al., 2023)

Other studies have examined the influence of HMI designs on TORs. One study showed that increasing the quantity of TOR visual information had minimal impact on system usability, but reduced driver task load and enhanced human-machine trust (Huang et al., 2024). Similarly, providing drivers with a direct indication of how and when to steer or brake is effective when navigating complex road geometry and critical takeover scenarios with low time headway (Brandenburg & Chuang, 2019). Additionally, certain HMI designs may result in improved takeover performance and driver comfort. An integrated TOR system provided on a personal device (e.g., smartphone) reduced takeover time and improved post-take-over performance compared to other conventional takeover requests, such as a TOR displayed on the in-vehicle interface (Talukder et al., 2024). Using an augmented reality HMI when providing drivers with information about takeover requests promotes safer driving behaviors (e.g., transitions, time to collision) and is associated with a wider acceptance among drivers (Liu et al., 2023; Merlhiot, 2024).

Current study

Although there have been a number of studies examining driver takeover performance and driver trust when driving a vehicle with lower levels of automation (i.e., level 2 or level 3), there have been no studies examining how navigating rural intersection designs with conditionally automated vehicles, such as J-turn intersections, influence driver decision-making and driver trust in conditionally automated vehicles. Therefore, the goal of this work was 1) to explore whether different rural intersection designs (e.g., non-traditional, traditional, roundabout) influence driver trust and comfort with a conditionally automated vehicle (i.e., level 3 SAE) navigating a rural intersection for them and 2) to identify any secondary factors that predict differences in driver trust and comfort with conditionally automated vehicles.

Research Questions

R_1: Do different rural intersection designs influence driver trust and comfort with conditionally automated vehicles?

R_2: What factors influence driver trust in a partially automated vehicle when navigating a rural intersection?

2. Method

Participants

A total of 275 participants were recruited to complete the study. Participants were included in the study if they were above 18 years of age, had a valid driver's license, and either owned or frequently drove on US roadways. Participants who completed the survey in less than 7.5 minutes were excluded from the study. After data cleaning, the final sample size consisted of 271 participants who completed the online study. The mean age was 44.7 years old (*SD* = 14.5) with a range of 20 to 83 years. Participants identified as white (*n* = 204 white or 75.3%), Black or African American (*n* = 31 or 11.4 %), Hispanic or Latino (*n* = 19 or 7.0%), Asian (*n* = 12 or 4.4%), multiracial (*n* = 4 or 1.5%) and American Indian or Alaska Native (n = 1 or < 1%). For education, *n* = 29 (10.3%) had a high school diploma or GED, *n* = 32 (11.8%) had an Associate's degree, *n* = 42 (15.5%) had some college, no degree, *n* = 99 (36.5%) had a Bachelor's degree, *n* = 68 (25.1%) had a graduate or professional degree, and *n* = 1 (< 1 %) had an "Other" degree no specified. Participants reported living in suburban (*n* = 151 or 55.7%), urban (*n* = 73 or 26.9%) and rural areas (*n* = 46 or 17.0%). Participants varied in their reported familiarity and experience with J-turn intersections. See Table 1. Finally, about half of participants (45 to 56%) reported having automated features in their current vehicles. See Table 2.

Table 1. Frequencies and Percentages of J-turn Familiarity and Experience

	n	**%**
J-turn Familiarity		
Never heard of J-turns	78	28.9
Heard of J-turns but not very familiar	41	15.1
Heard of J-turns and somewhat familiar	97	35.8
Heard of J-turns and very familiar	55	20.3
J-turn Experience		
Never crossed a J-turn	73	26.9
Crossed J-turn once or twice	87	32.1
Occasionally cross J-turns	89	32.8
Frequently cross J-turns	22	8.1

Table 2. Frequencies and Percentages of Vehicle Automation Features in Current and Future Vehicles

Automation Feature	**Yes** *n*	**No** *n*	**I don't know** *n*
Lane Departure Warning (LDW)			
Current Vehicle	130 (48.0)	128 (47.2)	13 (4.8)
Future Vehicle	205 (75.6)	27 (10.0)	39 (14.4)
Lane Keep Assist (LKA)			
Current Vehicle	123 (45.4)	133 (49.1)	15 (5.5)
Future Vehicle	197 (72.7)	29 (10.7)	45 (16.6)
Adaptive Cruise Control (ACC)			
Current Vehicle	153 (56.5)	93 (34.3)	25 (9.2)
Future Vehicle	200 (73.8)	27 (10.0)	44 (16.2)

Note. Percentages displayed in parenthesis.

Driving Simulator and Curated Video Development

Curated Videos. The curated videos were created in the Human Factors Safety Lab (HFSL) immersive, motion-based driving simulator manufactured (see Figure 1) by Realtime Technologies, Inc. The simulator consists of a 2013 Ford Fusion full-vehicle cab with realistic operation of controls and instrumentation including force feedback on the steering and realistic power assist feel for the brakes. The simulator is powered by the latest generation PCs with the latest generation simulation creation software that provides high-fidelity simulation for all sensory channels to generate a realistic presence within the simulated environment. The visual scene is projected through three new, high-lumen, high-resolution projectors and a seamless, cylindrical screen which will maximize the 210-degree forward horizontal field of view. Complimentary right and left LCD mirrors are embedded into the standard mirror housing of the chassis for an OEM look. A custom-fitted glass cockpit includes a dashboard cluster panel that can replicate any configuration of vehicle gauges and display. Auditory feedback pertaining to the driving world is provided by a 3D surround sound system.

Figure 1. HFSL immersive driving simulator

The videos were recorded by a member of the HFSL research team using a GoPro HERO9 Black camera. The GoPro was mounted to a mounting bracket between the two headrests of the vehicle, such that the interior of the vehicle and upcoming roadway was visible, including both sideview mirrors. The driver seat was positioned as far back and leaned as far back as would allow such that the driver was largely out of frame of the recordings. The researcher wore dark clothing and gloves to conceal the fact that there was someone operating the vehicle and to give the effect that the partially automated vehicle was driving through the intersection.

A total of 10 videos using five different intersections/scenarios, with or without the presence of traffic. The five recorded intersections/scenarios included a conventional intersection at a rural divided highway approaching from the minor road, two J-turn intersections approaching from the minor road, a roundabout, and a traditional work zone on a rural two-lane two-way roadway. Each of the intersections/scenarios are presented, via screenshots of the recordings, in Figure 2 through Figure 6.

Figure 2. Screenshot of simulated work zone intersection

Figure 3. Screenshot of simulated conventional intersection (traditional intersection)

Figure 4. Screenshot of simulated J-turn Intersection at Homestead Road (non-traditional intersection)

Figure 5. Screenshot of simulated J-turn Intersection in Huron Lake (non-traditional intersection)

Figure 6. Screenshot of simulated roundabout intersection (non-traditional intersection)

Measures

Scenario Specific Measures

Situational trust scale for automated driving (STS-AD). The situation trust scale for automated driving (STS-AD; Holthausen et al., 2020) assesses drive trust in the automated vehicle in each of the videos.

Trust in Automated Vehicle. One item asked participants to indicate how much trust they had in the automated vehicle navigating the intersection for them. The scale used a seven-point response set ranging from 1 = not at all to 7 = very much.

Comfort in Automated Vehicle. After each video, one item asked participants to indicate how comfortable they were with the automated vehicle navigating the intersection for them. The scale used a seven-point response set ranging from 1 = not comfortable at all to 7 = very comfortable.

Takeover Decision. After each video, participants were asked if they would have preferred to take over control driving through the intersection in this video. The scale used a binary response set (Yes/No).

J-turn Measures

J-turn Attitudes. Three items will assess participant J-turn attitudes using a seven-point Likert response set ranging from 1 = definitely not to 7 = definitely.

J-turn Experience. Two items will measure participants' prior knowledge and experience navigating J-turn intersections.

J-turns and Trust in Automation. Four items will ask drivers to indicate their comfort driving with an L2 automated vehicle driving them in general, their comfort while driving drowsy with L2 automation, and their comfort navigating a J-turn intersection with L2 automation. The items use a 5-point response set ranging from 1 = not comfortable at all to 5 = very comfortable. Drivers will complete these items before and after the simulation study.

Participant Characteristic Measures

Demographic information. Basic demographic information including participant age, gender, race, education, location (urban, rural, suburban) was collected prior to the simulation.

ADAS Features. Adapted from (Nordhoff et al., 2021). Participants were asked to indicate whether the primary vehicle they drove was equipped with ADAS technologies including Adaptive Cruise Control, Lane Keeping Assistance, and Lane Departure Warning (Yes/No/I don't know). Participants also reported whether they would like to have these technologies in their next vehicle (Yes/No/I don't know).

Procedure

In an online crowd-sourcing study conducted on UMN Qualtrics, a sample of licensed drivers were recruited from the crowd-sourcing website Prolific.com. Prior to beginning the online study, participants were provided with a study information sheet. The University of Minnesota IRB determined this research was exempt from IRB review (STUDY00025407). Participants completed basic demographic information and were then randomly assigned to either a traffic block or a non-traffic block of the five intersection curated videos. After watching each video of the simulated intersection, participants were asked whether they would like the simulated vehicle to proceed through the intersection using automation or whether they would like to take over control of navigating the intersection and rated subjective measures of trust and comfort with the automated vehicle in the video. After watching the five videos, participants completed J-turn attitude measures and a series of automation comfort measures. The average survey completion time was 18 minutes. Participants were compensated at a rate of $12/hour for their time, which is the rate recommended by the crowdsourcing website, Prolific.com.

Statistical Analysis

Prior to data analysis, the data was screened for missing data, checked for normality assumptions and any significant outliers were removed. Responses that were completed in less than 8 minutes were removed from the final data analysis. The five intersections were collapsed into three intersection groups: traditional (rural thru-STOP intersection), non-traditional (J-turn intersections and roundabout) and the work zone intersection. Random mixed-effects models examined the effects of intersection type (traditional, non-traditional and work zone) and takeover decisions (yes/no) on each of the AV trust items (STS-AD, AV Trust, AV Comfort) while considering the effects of J-turn experience (Yes/No), location (Rural, Urban, Suburban) and demographic factors (education and age). Traffic was treated as a random effect variable. Participant ID was treated as the repeated measures variable. Kenward-Roger Type 2 ANOVAs were applied to obtain denominator degrees of freedom for F-tests of the fixed effects in the model (Kenward & Roger, 1997).

3. Findings

Takeover Decisions by Intersection Type

Frequencies and percentages were computed for takeover decisions (yes/no) by intersection type (conventional, non-traditional, work zone). There were no significant differences between takeover decisions and type of intersection design with or without the presence of traffic (all p's > .05). Participants chose to take over control driving more often than not (about 60% of the time) in each of the different simulated driving scenarios. See Table 3.

Table 3. Frequencies and percentages of takeover decision by driving scenario

	Takeover Decision			
	Yes		No	
	n	%	*n*	%
Traffic				
Traditional	83	62.9	49	37.1
Non-Traditional	245	61.4	154	38.6
Work Zone	77	57.5	57	42.5
No Traffic				
Traditional	77	56.6	59	43.4
Non-Traditional	242	59.5	165	40.5
Work Zone	84	62.2	51	37.8

Next, means, standard deviations and Pearson's correlation coefficients were computed for each of the trust and comfort measures by intersection type. See Table 4. Overall, situational trust, AV trust and AV comfort measures were reported as relatively moderate across all intersection types, with and without traffic. See Table 4. The STS-AD was significantly positively correlated with AV Trust, $r = .84$ ($p < .001$) and AV Comfort, $r = .85$, ($p < .001$) measures and AV Trust and AV comfort were significantly positively correlated, $r = .93$ ($p < .001$) providing evidence of convergent validity for each of the dependent variables.

Table 4. Means and Standard Deviations of STS-AD, AV Trust and AV Comfort Measures by Intersection Type with and without Traffic

	STS-AD		AV Trust		AV Comfort	
	M	*SD*	*M*	*SD*	*M*	*SD*
Traffic						
Traditional	3.75	.99	4.12	1.74	3.88	1.84
Non-Traditional	3.81	.92	4.17	1.64	4.00	1.78
Work Zone	3.86	.95	4.31	1.70	4.23	1.81
No Traffic						
Traditional	3.88	.92	4.30	1.67	4.17	1.75
Non-Traditional	3.87	.89	4.29	1.71	4.14	1.81
Work Zone	3.72	.96	4.16	1.80	3.97	1.86

Note. STS-AD uses a 6-point response set, AV Trust and AV comfort use a 7-point response set

Predictors of Trust and Comfort with Automated Vehicles

Predictors of Situational Trust (STS-AD). There was a significant effect of education on situational trust, $F(5, 259.89) = 2.31$, $p = .045$. Those with a graduate or professional degree (i.e., more education) showed to have the highest situational trust, *emm* = 4.05 (*SE* = .16). There was a significant effect of J-turn experience (yes/no) on situational trust, $F(1, 260.66) = 9.72$, $p = .002$. Those with previous J-turn experience showed higher situational trust scores compared to those who had never driven on a J-turn intersection, mean difference = .25 (*SE* = .08). See Figure 7. There was a significant effect of takeover decision (1, 1280.44) = 726.18, $p < .001$ on situational trust. Participants who opted to take over control showed significantly lower situational trust scores compared to those who did not opt to take over control of the automated vehicle, mean difference = .966 (*SE* = .034). See Figure 8. There was a marginally significant effect of location on situational trust, $F(2, 259.67) = 2.63$, $p = .051$, with those living in urban areas having marginally greater trust compared to those living in suburban areas, mean difference = .22 (*SE* = .08). See Figure 9. There were no significant effects of intersection type or age on situational trust.

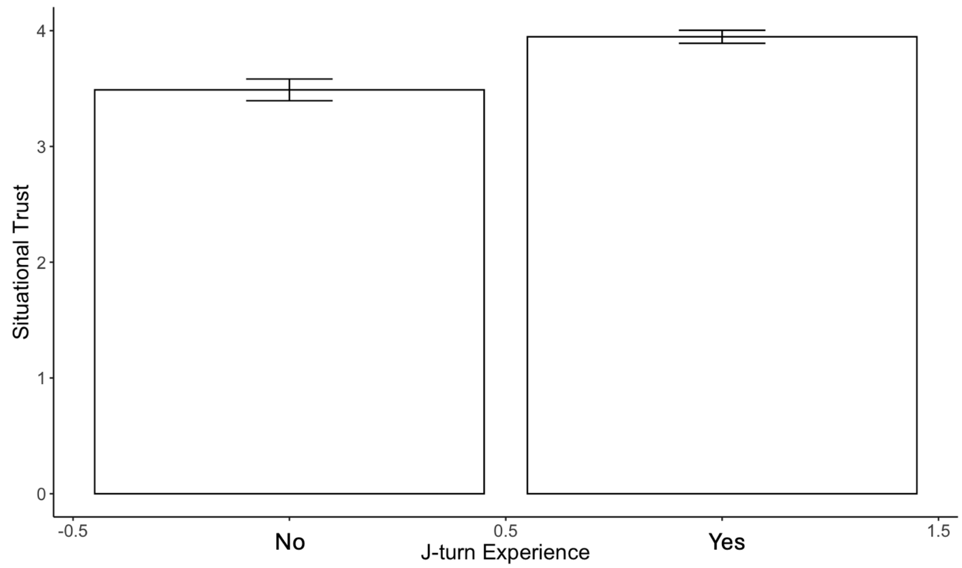

Figure 7. Bar Graph of J-turn Experience (No/Yes) and Mean Situational Trust Score

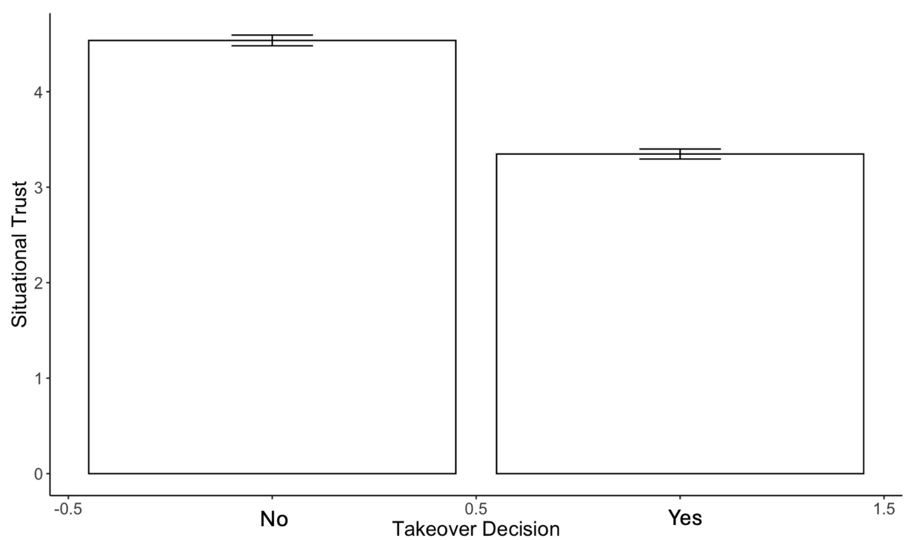

Figure 8. Bar Graph of Takeover Decision (No/Yes) and Mean Situational Trust Score

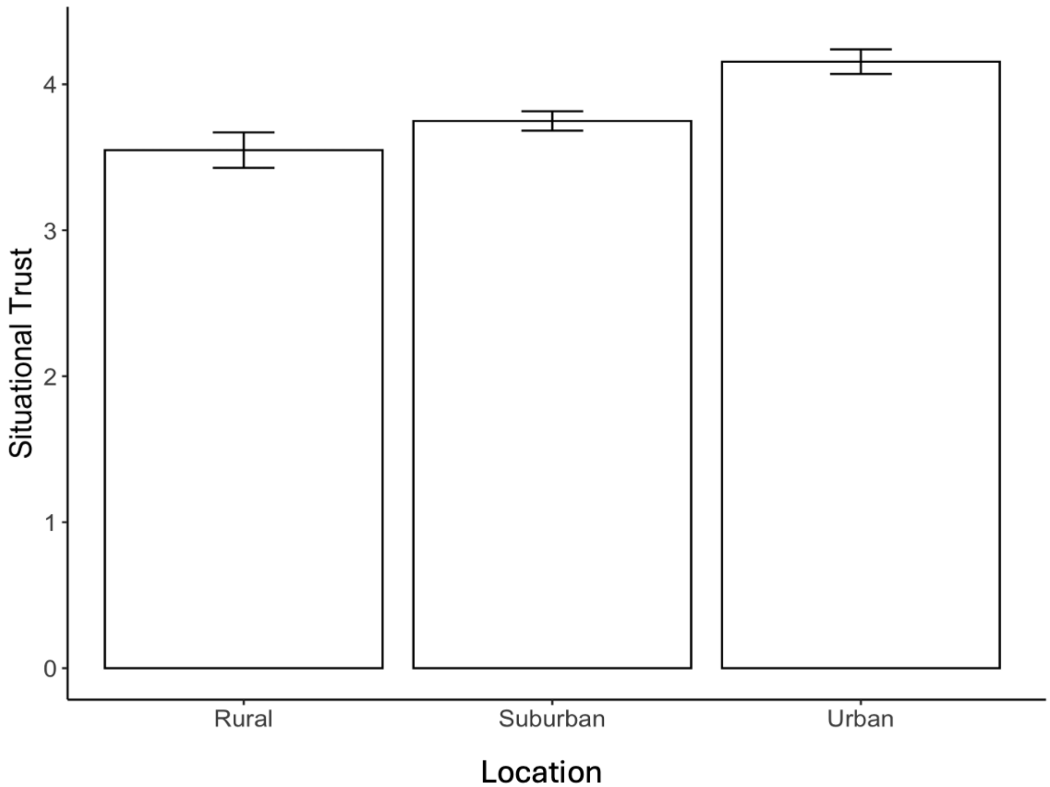

Figure 9. Bar graph of location (Rural, Suburban, Urban) and Mean Situational Trust Scores

Predictors of AV Trust. There were significant effects of education on AV trust, $F(5, 259.86) = 2.86$, $p = .02$. Participants with higher education (i.e., graduate/professional degree) showed the highest trust with AVs, *emm* = 4.94 (*SE* = .28). There were significant effects of J-turn experience on AV trust, $F(1, 260.67) = 7.24$, $p = .007$. Experience with J-turns showed higher trust with the AV compared to no experience with driving on J-turns, mean difference = .39 (*SE* = .14). There were significant effects of location on AV trust, $F(2, 259.90) = 6.62$, $p = .0003$. Rural drivers showed significantly less trust compared to urban drivers, mean difference = .77 (*SE* = .20), $p = .0011$. Suburban drivers showed significantly less trust compared to urban drivers, mean difference = .52 (*SE* = .15), $p = .0031$. There were significant effects of takeover decisions on AV trust, $F(1, 1291) = 656.47$, $p < .0001$. Drivers who opted to take over control showed significantly lower trust compared to those who did not opt to take control, mean difference = 1.69 (*SE* = .06). There were no significant effects of intersection type or age on situational trust.

Predictors of AV Comfort. There were significant effects of education on AV comfort, $F(5, 259.97) = 3.07$, $p = .01$. Participants with higher education (i.e., graduate/professional degree) showed the highest comfort with AVs, *emm* = 4.77 (*SE* = .29). There were significant effects of J-turn experience on AV comfort $F(1, 260.70) = 14.42$, $p = .0002$. Experience driving on J-turn intersections showed higher comfort with AVs compared to those without previous J-turn experience, mean difference = .56 (*SE* = .15). There were significant effects of location on AV comfort, $F(2, 259.98) = 7.04$, $p = .001$. Rural participants had significantly less trust compared to urban participants (mean difference = .852, *SE* = .21), $p = .0003$ and suburban participants had significantly less trust than urban participants (mean difference = .53, *SE* = .15), $p = .003$. There were significant effects of takeover decision on AV trust, $F(1, 1295.14) = 712.67$, $p < .0001$. Those who opted to take over control showed significantly lower trust compared to those who did not opt to take over control (mean difference = 1.82, *SE* = .09). There were no significant effects of intersection type or age on situational trust.

Predictors of Comfort with L3 SAE AVs Driving on J-turn Intersections

Next, a linear regression model was computed to examine whether certain demographic and J-turn attitude and experience measures were predictors of self-reported comfort with level 3 SAE automated vehicles driving on J-turn intersections. Predictors of comfort with an level 3 SAE driving on a J-turn included education, with those with some college, no degree being significantly less likely to be comfortable having a level 3 AV driving for them on a J-turn, $B = -.63$ ($SE = .25$), $p = .012$, the total number of automation features in their current vehicles, with more automation features predicting more support for AVs driving on J-turns, $B = .11$ ($SE = .05$), $p = .034$, and the attitude that J-turns were a good idea, $B = .17$ ($SE = .08$), $p = .036$. J-turn experience (yes/no), location (i.e., living in urban, rural, suburban area), willingness to drive on J-turns, support for J-turns being placed in the community, and age were not predictive of comfort with level 3 SAE automated vehicles driving on J-turns.

Data Repository

Finally, this work led to the development of low-cost, scalable simulations for future research investigations and other research teams into rural intersections and intersection designs. A data repository was made available on the data repository for the University of Minnesota (DRUM). The available data includes each of the 10 curated videos of the simulated drives, in both the raw uncut form and the edited/cut videos used in the study as well as the final dataset ($N = 271$ participants) with a corresponding codebook. The data hosted in the repository will be assigned a Digital Object Identifier (DOI) to enable persistent access and formal data citation. This will support others to access the data and videos, both in raw uncut form as well as the same edited/cut videos implemented, potentially providing a mechanism for longitudinal tracking of takeover decisions and trust in automation among urban, suburban, and rural populations over time.

Summary of Findings

The purpose of this work was to determine whether 1) the type of rural intersection design influenced driver trust and comfort with conditionally automated vehicles and 2) explore secondary factors that influenced driver trust in partially automated vehicles. This work took an exploratory approach to understand whether there were differences in driver trust and comfort with conditionally automated vehicles navigating various rural intersections. Overall, driver trust and comfort with automated vehicles did not differ by the type of intersection design but was primarily predicted by driver takeover decisions and certain driver characteristics.

The findings from this work showed that the type of rural intersection design (i.e., non-traditional intersection, traditional intersection) did not influence driver trust and comfort with automated vehicles navigating the intersection for them. Instead, driver trust and comfort with conditionally automated vehicles was relatively similar across all intersection designs.

However, there were secondary factors that predicted differences in driver trust and comfort with conditionally automated vehicles including driver takeover decisions and certain driver characteristics. Specifically, takeover decisions strongly predicted each of the measures of trust and comfort with automated vehicles. Drivers who chose to take over control of the automated vehicle reported having much lower trust and comfort in the automated vehicle navigating the intersection for them compared to those who chose not to take over control. As discussed previously, the safety advancements of automated vehicles are expected to further reduce serious injury and fatal crashes at high-risk intersections, such as J-turn intersections. However, the findings from this work suggest that when given the choice, drivers may be prone to manual takeovers at the intersection, risking a potential loss of safety that the automation could provide in decisions such as safe gap selection.

There may be a need to further explore drivers' decisions to takeover control. Not only examining more sensitive takeover decisions (e.g., takeover time), but to consider the role of other factors in a decision to take over control. A meta-analysis and systematic review found that factors such as heads-up displays, takeover request alerts and higher traffic volumes were associated with shorter takeover times, while urgent takeover requests, gender, increased time budgets and additional lanes were associated with longer takeover times (Sekadakis & Yannis, 2025).

Additionally, drivers with higher education and previous J-turn experience reported greater trust and comfort in automated vehicles navigating the intersection for them. There were also effects of participant location on some of the trust and comfort measures. Participants living in urban areas showed to have more trust and comfort with the automated vehicle driving for them compared to those living in rural or suburban areas.

The analysis examining predictors of comfort with L3 automated vehicles driving on J-turn intersections revealed that greater comfort with L3 automated vehicles driving on J-turn intersections was predicted by education level, the total number of automated features in their current vehicles, and the belief that J-turns were a good idea.

Finally, the outcome of this work led to the development of low-cost, scalable simulations for future research investigations and other research teams into rural intersections and intersection designs.

4. Recommendations

Given the strong effect of takeover decisions on driver trust and comfort with conditionally automated vehicles, it is important to further understand drivers' decisions to takeover control to better improve driver trust and comfort with conditionally automated vehicles. Understanding takeover decisions may be better understood through in-depth interviews or through more sensitive measures of takeover decisions that could be captured in a driving simulation study (e.g., time to takeover, reaction time to takeover requests).

Given that past work suggests that drivers report being more comfortable with highly automated vehicles (i.e., level 4 and level 5 automation) and that there may be individual differences that influence driver comfort with varying levels of automation (Schwieters et al., 2021), it is recommended that future work explore whether these factors interact with and differ when presented with diverse driving environments using different levels of automation (e.g., Level 2 and Level 5).

A potential key avenue for improving trust and comfort with automation may be via exposing and educating drivers about automated vehicles, particularly in regard to their capabilities and ability to navigate different types of intersections through education and public outreach. Familiarity/knowledge of different types of intersections may give way to increased comfort and trust with different levels of automation. Customizing messaging and educational content may be necessary based on the unique needs of the community (e.g., geographic location).

5. Challenges and Lessons Learned

This study focused on examining differences in driver trust and comfort when an automated vehicle was navigating various types of rural intersections. Given the lack of differences in driver trust and comfort ratings across the different types of rural intersections presented, it is possible that trust and comfort in conditionally automated vehicles are relatively stable traits regardless of the type of roadway driven. However, differences in driver trust and comfort with conditionally automated vehicles may differ when they are exposed to different driving environments (e.g., urban roadways and rural roadways), especially given that trust and comfort ratings differed by participant's geographic location (i.e., living in urban, suburban or rural area). Presenting drivers with more diverse simulated driving environments may help identify interactions between participant characteristics and driving environment and their influence on driver trust and comfort.

The use of an online crowd sourcing study is a cost-saving and accessible method for an exploratory approach to examine takeover decisions and trust with conditionally automated vehicles. However, this method does not allow for the high-fidelity simulated experience of an automated vehicle navigating various intersection designs. Therefore, it is necessary that a follow up study be conducted using the Human Factors Safety Laboratory driving simulator to fully immerse participants in a simulated experience of a conditionally automated vehicle navigating different types of rural intersections and to collect more sensitive measures of driver behavior and takeover decisions (e.g., takeover time), not measurable through an online crowd sourcing study.

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Appendix A: Survey Metrics

Pre-Study Survey

1. Do you agree to participate in this study?
    a. Yes
    b. No
2. Do you have a valid driver's license?
    a. Yes
    b. No
3. What is your age?
4. Have you heard of partially automated vehicles?
    a. Yes
    b. No
5. What is the make and model of the primary vehicle which you drive?
6. What year is the primary vehicle which you drive?
7. Is the Lane Departure Warning (i.e., Lane Departure Alert) active in the primary vehicle which you drive?
    a. Yes
    b. No
    c. I don't know
8. Would you choose to have Lane Departure Warning (i.e., Lane Departure Alert) technology in your next vehicle?
    a. Yes
    b. No
    c. I don't know
9. Is the Lane Keeping Assistance (i.e., Lane Sensing, Lane Departure Assist) active in the primary vehicle which you drive?
    a. Yes
    b. No
    c. I don't know
10. Would you choose to have Lane Keeping Assistance (i.e., Lane Sensing, Lane Departure Assist) technology in your next vehicle?
    a. Yes
    b. No
    c. I don't know
11. Is the Adaptive Cruise Control (Dynamic Cruise Control) active in the primary vehicle which you drive?
    a. Yes
    b. No
    c. I don't know
12. Would you choose to have Adaptive Cruise Control (Dynamic Cruise Control) technology in your next vehicle?
    a. Yes
    b. No
    c. I don't know
13. What is your highest level of education?
    a. Some high school
    b. High school diploma or GED
    c. Associate's degree
    d. Some college, no degree
    e. Bachelor's degree

f. Graduate or professional degree
g. Other (text entry)

14. What is your race?
    a. American Indian or Alaska Native
    b. Asian
    c. Black or African American
    d. Hawaiian or Other Pacific Islander
    e. White
    f. Hispanic or Latino
    g. Multiracial
    h. Other (text entry)
15. Do you consider yourself to live in an urban, suburban, or rural area?
    a. Urban
    b. Suburban
    c. Rural
16. In which area(s) do you drive most often? Please check all that apply
    a. Urban
    b. Suburban
    c. Rural

Per-Video Survey

1. Would you have preferred to take over control driving through the intersection in this video?
    a. Yes
    b. No
2. How much do you trust the automated vehicle to navigate the intersection in this driving scenario? (1 - Not at all to 7 - Very much)
3. How comfortable would you be with the automated vehicle driving for you through the intersection in this driving scenario? (1 - Not comfortable at all to 7 - Very comfortable)

The following items ask you about the automated vehicle in the video driving scenario you just experienced. Please read each of the following items carefully and indicate the degree to which you agree with each statement. (1 - strongly disagree to 7 - Strongly agree)

4. I trust the automated vehicle in this driving scenario
5. I could perform better than the automated vehicle in this driving scenario
6. In this driving scenario, the automated vehicle would perform well enough for me to engage in other activities (such as reading)
7. This driving scenario was risky
8. The automated vehicle would make an unsafe judgement in this driving scenario
9. The automated vehicle would react inappropriately to this driving environment

Post-Study Survey

1. How much experience do you have crossing J-turn intersections?
    a. I have never crossed a J-turn
    b. I have crossed a J-turn once or twice
    c. I occasionally cross J-turns
    d. I frequently cross J-turns
2. How familiar are you with J-turn intersections?
    a. I have never heard of J-turns
    b. I have heard of J-turns but am not very familiar
    c. I have heard of J-turns and am somewhat familiar
    d. I have heard of J-turns and am very familiar

3. Do you think J-turns are a good idea? (1 - Definitely not to 7 - Definitely)
4. Are you willing to drive on a J-turn (1 - Definitely not to 7 - Definitely)
5. Would you be supportive of a J-turn to be placed in your community (1 - Definitely not to 7 - Definitely)

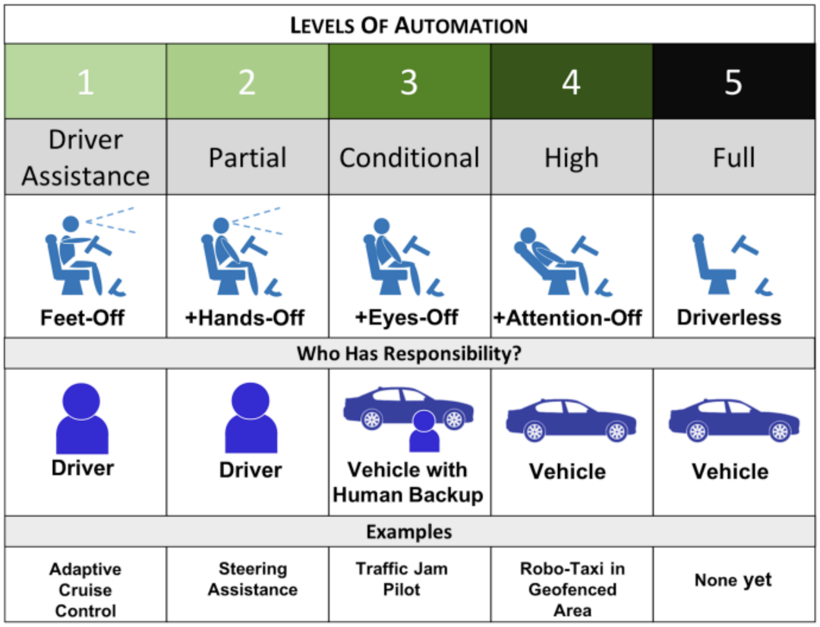

Image Adapted from UNITY Consulting and Innovation

6. How comfortable are you driving when you are tired enough to be nodding off at the wheel? (1 - Not comfortable at all to 5 - Very comfortable)
7. How comfortable would you be driving on a J-turn when you are tired enough to be nodding off at the wheel? (1 - Not comfortable at all to 5 - Very comfortable)
8. How comfortable are you driving with a **Level 3 automated vehicle** driving for you when you are tired enough to be nodding off at the wheel? (1 - Not comfortable at all to 5 - Very comfortable)
9. How comfortable would you be with a **Level 3 automated vehicle** driving for you on J-turn intersection? (1 - Not comfortable at all to 5 - Very comfortable)
10. How comfortable would you be with a **Level 3 automated vehicle** driving for you on J-turn intersection when you are tired enough to be nodding off at the wheel? (1 - Not comfortable at all to 5 - Very comfortable)

Appendix B: Final Documentation of Outputs, Outcomes, and Impacts

Outputs

1. Driving simulation programming of a series of J-turn intersections
2. Study design utilizing video of simulated J-turn intersections from driving simulator
3. Design and methodology for a simulation video database with accessible files.
4. Schwieters, K. R., Craig, C. M., & Morris, N. L. (2025). An Evaluation of Persuasive Messaging Factors and Strategies on Attitude Change Toward J-Turn Intersections. Poster Presentation and Conference Proceedings paper in the Transportation Research Board Annual Meeting
5. Morris, N. L., Drahos, B. A., Easterlund, P. & Schwieters, K. R. (2026). Meets the Road: Evaluating the Influence of Stop Line Position on Driver Stopping Distances at Rural Stop-Controlled Intersections. Paper Presentation and Conference Proceedings paper in the Transportation Research Board Annual Meeting.
6. Accessible simulated videos and dataset made available on the University of Minnesota's Data Repository (DRUM): https://hdl.handle.net/11299/278984
7. Presentation of research findings at the CCAT Research Review

Outcomes and Impacts

1. Increased understanding and awareness of a gap in the existing research on the impact of level 2/level 3 SAE automated vehicles on driver trust while navigating J-turn intersections and other novel roadways, as well as the influence of eHMI in promoting driver trust in automation, driver decision making through an extensive literature review.
2. Increased understanding and awareness of navigating J-turn intersections for 197 undergraduate and graduate students in human factors, ISYE, ME, and biomedical engineering.
3. Increased understanding of the role of takeover decisions and other driver factors influencing driver trust and comfort with level 3 SAE automated vehicles navigating different types of simulated rural intersections.
4. Support driver performance and to improve trust in using ADAS technologies at complex intersections and to guide education, digital interfaces, and infrastructure decision making, guidance, and implementation.
5. Inform design decisions at J-turn intersections to further reduce conflicts and mitigate the effects of severe crashes at divided highway, thru-STOP intersections.
6. Provide low-cost, scalable simulations for future research investigations and other research teams into rural intersections and intersection designs.